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THE EFFECTS OF MANAGEMENT INITIATIVES ON THE COSTS AND SCHEDULES OF DEFENSE ACQUISITION PROGRAMS

Volume I: Main Report

Karen W. Tyson, *Project Leader*
Neang I. Om
D. Calvin Gogerty
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Daniel M. Utech

November 1992

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Tactical Systems

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This two-volume paper examines trends in the outcomes (in terms of costs and schedules) of the acquisition programs for major weapon systems, and assesses the effectiveness of management initiatives in improving these outcomes. IDA analyzed a total of 116 major programs that included a mix of aircraft, tactical munitions, electronics/avionics, strategic missiles, satellites, vehicles, and ships. In Volume I of the paper, program outcomes are assessed by equipment type, by time period, by phase (development and production), and by type (new or modification). The initiatives assessed are prototyping, contract incentives, multi-year procurement, design-to-cost, dual-source competition, and total package procurement and fixed-price development. Volume II contains special analyses of ships and ground combat programs. The management initiatives that show the most promise for containing cost and schedule growth are prototyping, contract incentives, and multi-year procurement.

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INSTITUTE FOR DEFENSE ANALYSES

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PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Deputy Director, Defense Research and Engineering (Tactical Systems), under contract MDA 903 89 C 0003, Task Order T-F7-799, issued 15 March 1990, and amendment. The objective of the study was: (1) to add ground combat and ship programs to the existing IDA database of defense acquisition program data and (2) to analyze the effects of applying management initiatives on the costs and schedules of those programs. This is the first of two volumes reporting on the results of that task. This volume assesses the patterns of cost and schedule growth and the effectiveness of management initiatives for all programs in the database. Volume II presents the analyses of the ground combat and ship programs that were added to the database.

This paper was reviewed within IDA by Stanley A. Horowitz, Barbara A. Bicksler, and An-Jen Tai.

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The authors wish to express their appreciation to the many individuals and organizations who contributed to this study. We would like to thank Mr. Frank Kendall, Director (Tactical Systems), who sponsored the work, and Lt. Col. Norris L. McCall and Brig. Gen. R. W. Wharton, who served as cognizant officials for the study. We appreciate the assistance of Mr. Gary Christle and Mr. Larry Axtell of the Office of the Under Secretary of Defense (Acquisition), who provided data and information to the study team.

We would also particularly like to thank the many members of the staffs of the U.S. Army and the U.S. Navy who assisted us in adding ground combat programs and ships, and the staff people from other organizations that contributed information to the study, including:

- Office of the Secretary of Defense
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- The Boeing Company
- General Dynamics Corporation
- General Electric Company
- Grumman Aerospace Corporation
- Hughes Aircraft Company
- Martin Marietta Corporation
- McDonnell Douglas Corporation
- Raytheon Company
- Rockwell International Corporation
- Texas Instruments, Incorporated
- United Technologies Corporation, Pratt & Whitney.

CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

Acquisition programs have had varying degrees of success in developing and producing weapon systems on time and within budget. Today, it is more important than ever that programs to acquire systems be carefully designed and managed. The results of past programs hold lessons for the future.

We found that, on average, major weapon system programs cost roughly half again as much as originally planned, and systems took one-third longer to develop than planned. There was, of course, great variability in these measures depending on program characteristics.

The equipment types with the highest cost growth were tactical munitions and vehicles, and ships had the lowest. Vehicles and air-launched tactical munitions had the highest development schedule growth, and tactical aircraft had the lowest. There was little indication that outcomes are getting substantially better or worse over time, although they have improved since the 1960s.

For most weapon types, systems that had a predecessor system had lower cost growth, because they usually are less risky technically. However, for air-launched tactical munitions, vehicles, and electronic aircraft, modification programs were often as difficult as completely new ones.

Prototyping, multi-year procurement, and development contract incentives appeared to help to reduce cost growth. Early implementation of a design-to-cost strategy may be useful, but quantitative results are incomplete. The results for dual-sourcing in production were mixed. Fixed-price development and total package procurement were unsuccessful.

OBJECTIVE AND APPROACH

How well have past systems adhered to their cost and schedule plans? Has the institutionalization of the acquisition process helped or hurt? Have there been some times in history when things turned out better, or are problems inevitable? What are the causes of cost overruns and schedule slippages? What management strategies have been most successful? What kinds of systems are most likely to have trouble, and why? What can the Defense Department do to improve program outcomes?

To help answer some of these questions, IDA developed measures of cost and schedule growth for 11 types of equipment developed since the 1960s. We analyzed differences in the measures by equipment, by time period, by phase, and by whether the program was entirely new or a modification of an earlier system (development type). We also examined the effectiveness of six management initiatives in improving these outcome measures. The initiatives assessed were:

- Prototyping,
- Contract incentives,
- Multi-year procurement,
- Design-to-cost,
- Dual-sourcing, and
- Total package procurement and fixed-price development.

IDA analyzed 116 major programs that are part of the reporting system set up by the DoD, the Selected Acquisition Reports (SARs). In each case, we compared the results of the program as of the final 1989 SAR with the plan for the program approved at the Milestone II meeting, the time at which the program is given permission to proceed into engineering and manufacturing development (EMD). [For most of the historical period we examined, this phase was called full-scale development (FSD).]

The database includes a mix of aircraft (tactical, electronic, bomber, transport, and helicopters), tactical munitions (both air-launched and surface-launched), electronics programs, strategic missiles, satellites, vehicles, and ships. We set minimum data standards for programs in order to have development and production outcome measures calculated. One hundred programs met the development standard, and 82 programs met the production standard. We also identified the management strategies applied to the programs, with special attention to the vehicles and the ships that were new to the database.

PATTERNS IN ACQUISITION PROGRAM OUTCOMES

On average, total program cost growth was 47 percent—29 percent in development and 56 percent in production. Development schedules (Milestone II to initial operational capability) grew by an average of about one-third over the plan. There is, of course, great variability in these measures depending on program characteristics.

As shown in Figure ES-1, the equipment types with the highest total program cost growth were tactical munitions (103 percent) and vehicles (96 percent). The lowest cost growth was exhibited by ships (15 percent). The highest development cost growth was for vehicles (104 percent) and electronics/avionics programs (78 percent), and the lowest was for strategic missiles (5 percent).

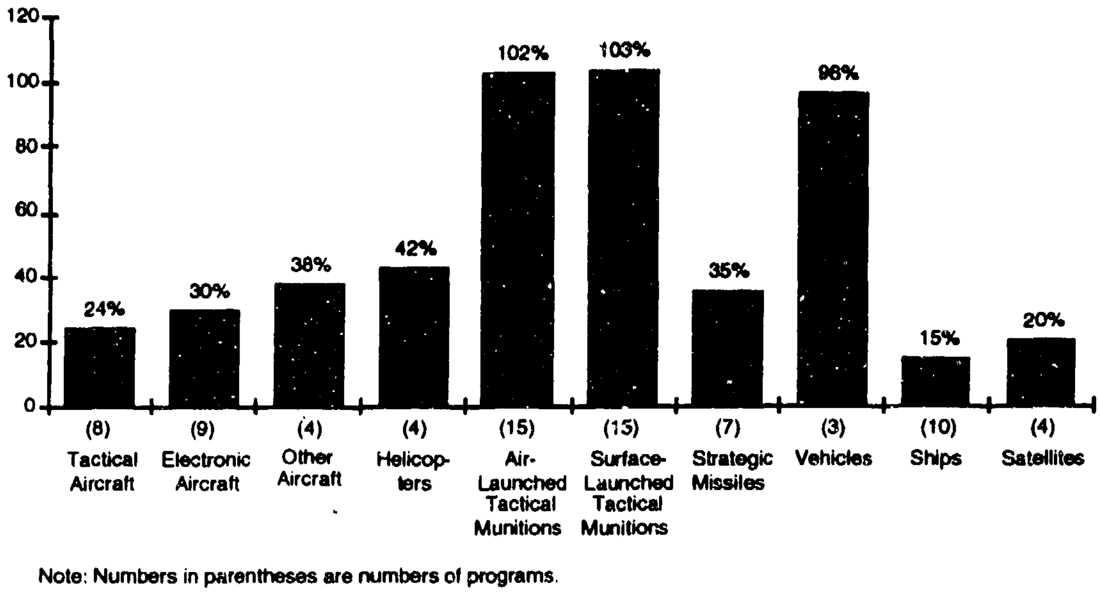


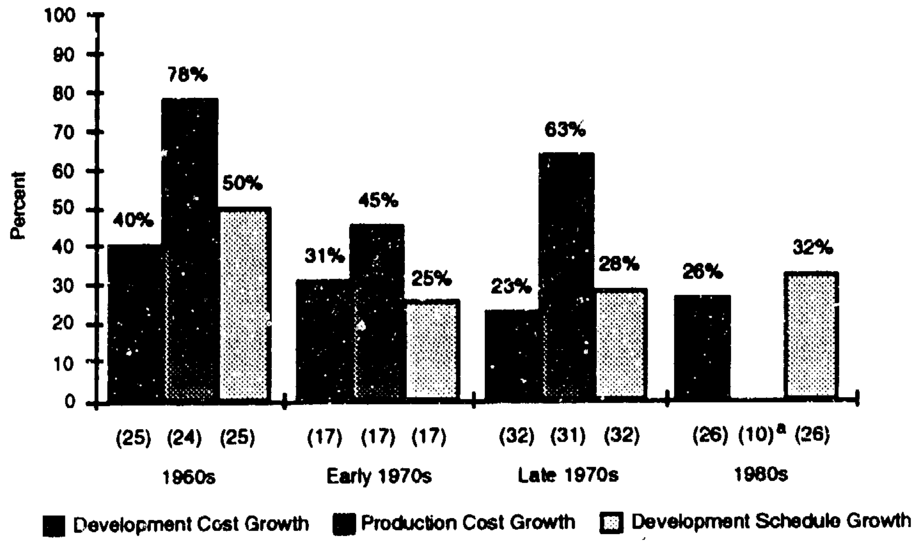
Figure ES-1. Total Program Cost Growth by Equipment Type

Development schedules are important—the system should be ready when planned in case it is needed for combat. The equipment types with the highest development schedule growth were vehicles and air-launched tactical munitions, while the type with the lowest was tactical aircraft.

We looked at programs by time period in order to determine whether particular times yielded particularly favorable acquisition outcomes. We grouped programs into time periods according to their FSD start years, because acquisition strategies are often determined by that point. Figure ES-2 shows key outcomes by time period.

There is little indication that acquisition program outcomes are getting either substantially better or substantially worse. Outcomes were worst in the 1960s, and they have improved since then. However, the improvement has not been continuous. Cost growth remains a persistent problem, despite improvements in management procedures.

The jury is still out on the 1980s-era programs. The ten programs for which we have sufficient data to measure total program cost growth are staying within their planned costs. This is a hopeful sign. However, cost growth tends to accumulate with experience, and these programs are incomplete. Moreover, development schedule growth, a key indicator of future problems, was higher in the 1980s than in the 1970s.



Note: Numbers in parentheses are numbers of programs.
[a] Only 10 cases available—see discussion in Chapter IV.

Figure ES-2. Summary of Outcomes by Time Period

We would expect that programs that succeed very similar systems (dubbed modification programs, or mods) would have lower cost growth than completely new programs. Here, there were some surprising results. As we expected, modifications had lower cost growth than new systems overall. For some equipment types, however, the technical difficulty of modification programs is underestimated just as much as that of new programs, resulting in cost growth. This growth was particularly seen in air-launched tactical munitions in development and for vehicles and electronic aircraft in production.

RESULTS FROM ASSESSMENT OF ACQUISITION INITIATIVES

Acquisition managers should consider making more use of prototyping. Prototyped programs had lower mean total program cost growth than non-prototyped programs. Prototyping before FSD significantly reduced development cost growth in the tactical munitions programs, where the programs with the greatest technical risk were prototyped. The major goal of prototyping is to reduce technical risk; however, it also reduces cost growth, particularly for technically challenging programs. Figure ES-3 shows program outcomes for the two major equipment groups that used prototyping the most.

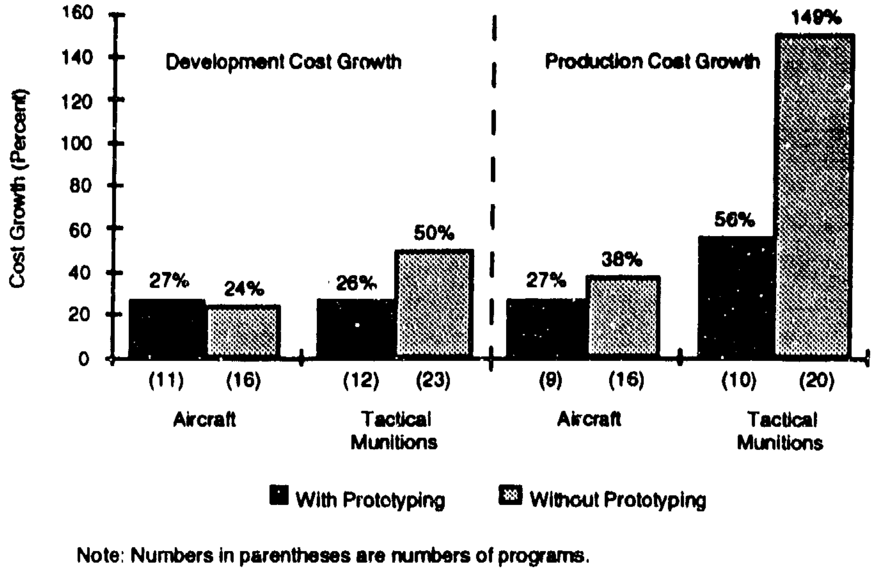
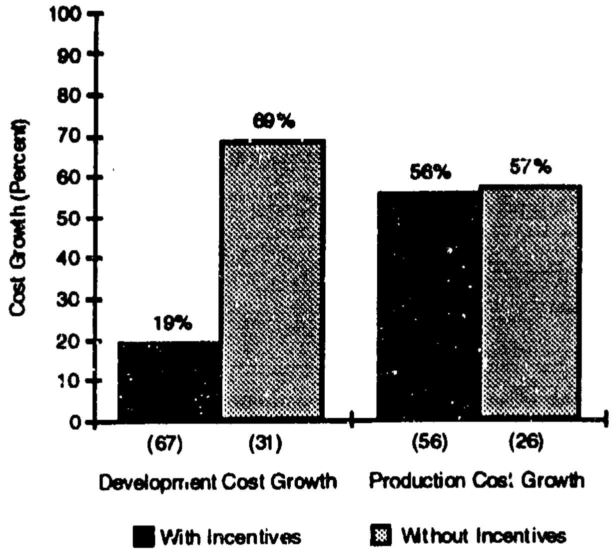


Figure ES-3. Outcomes for Programs With and Without Prototyping

Among aircraft programs, those with less technical risk were prototyped, and prototyping was less successful. If development cost can be made more predictable, the DoD's credibility would be enhanced in developing support for further investments in a program. This study did not specifically address a more recent idea, the increased use of advanced technology demonstrators without production. More study is needed of this new strategy. However, our results do have one implication for the "new prototyping" issue. The research we have undertaken shows the practical value of the SAR reporting system in providing data for monitoring and evaluating acquisition programs. While the SARs have imperfections, they are extremely valuable. The use of advanced technology demonstrators should not diminish the importance of cost and schedule estimating, reporting, and monitoring.

Well-designed contract incentives are an inexpensive way to induce contractors to reduce costs. Figure ES-4 shows development cost growth for programs with and without FSD contract incentives and production cost growth for programs with and without production contract incentives. Development cost growth is significantly lower in programs with incentive contracts in FSD. For incentive contracts in production, the results are not statistically significant, but different contract types are typically used at different stages of production. These results were intuitively appealing. Much more information is needed on how to design and time incentives so that they work best.

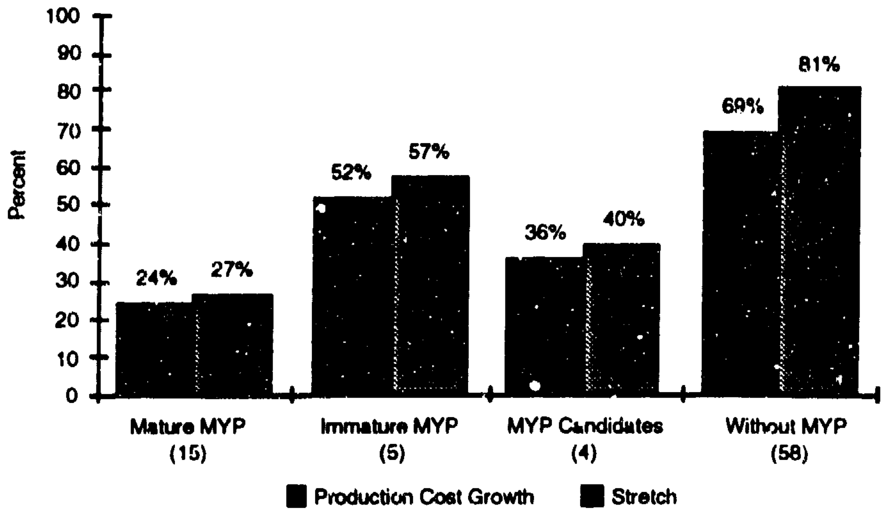


Note: Numbers in parentheses are numbers of programs.

Figure ES-4. Cost Growth and Contract Incentives

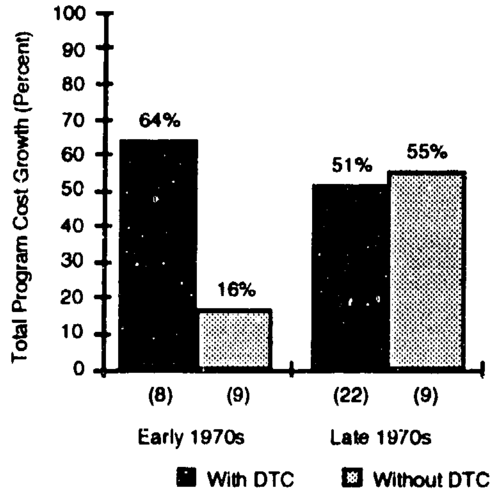
Multi-year procurement (MYP) appears to be a successful initiative, as practiced by the DoD using congressional guidelines. We assigned programs to one of four groups, mature MYP programs (those with three or more years of MYP experience), immature MYP programs (those with current MYP contracts, but with less than three years of experience), MYP candidates (those considered but not approved), and programs that were not official candidates for MYP. Figure ES-5 compares outcomes among the four groups of programs. Production outcome measures are considerably better for the mature MYP programs than for the non-MYP programs. However, our results do not guarantee success if multi-year procurement is increased. MYP implies some protection from budgetary pressures, and it is impossible to offer such protection to all programs. Non-MYP programs were stretched out more often. To a certain extent, the programs that were procured using MYP were allowed this privilege because they were already successfully managed.

Design-to-cost (DTC) needs to be implemented early to be successful; otherwise, it does not make sense. Figure ES-6 shows that the initial implementation of DTC in the early 1970s was not successful. In the late 1970s, DTC programs had slightly lower cost growth, and it is too early to tell about the 1980s programs. Our case analyses and breakdowns of results show that the successful implementations of DTC are those that apply the initiative early in the demonstration/validation phase, before design decisions are set.



Note: Numbers in parentheses are numbers of programs.

Figure ES-5. Key Variables for Programs With and Without MYP



Note: Numbers in parentheses are numbers of programs.

Figure ES-6. Average Cost Growth for Programs With and Without DTC

The record for dual-sourcing is mixed. Figure ES-7 shows the outcomes from the full sample and from tactical munitions and ships (where virtually all the dual-sourcing in our group of programs occurred).

Both equipment types show improved cost growth with dual-sourcing. However, it appears that at least some of the positive effect of dual-sourcing results from the fact that such programs are less likely to be stretched. Dual-sourcing can be of value in individual cases. In the current environment, when it is going to be difficult for the government to fund even one source, competition should be considered carefully. In evaluating individual cases of dual-sourcing, it is important to consider the cost of bringing on the second source.

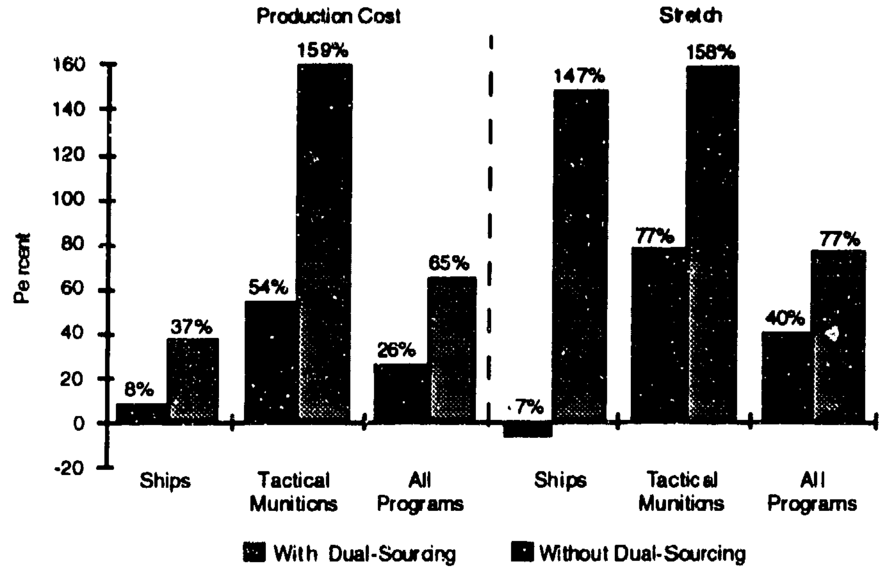


Figure ES-7. Outcomes for Programs With and Without Dual-Sourcing

The era of fixed-price development (FPD), the early 1980s, is now over. Our results indicate that it should not be revived (see Figure ES-8). In high-risk programs, the government often was forced to reopen the contract when the contractor was unable to fulfill the terms of the original contract. Cost growth was higher in fixed-price development programs, and problems in development often spilled over into production. This initiative should not be used in high-risk programs.

During the 1960s, the government tried to shift risk to contractors by requiring contractors to bid on development and production and sometimes support work under one contract. Cost growth in both development and production is substantially higher in programs that used the total package procurement (TPP) concept (see Figure ES-9). While the goal of the TPP concept was desirable, the quantum leap in acquisition practice that implementation of the concept represented was a factor in its failure.

DoD can use the information in this study to target the types of programs that showed the highest cost and schedule growth—the tactical munitions, vehicles, and electronics/avionics programs—for increased management attention. One can also see the benefits of using common subsystems from the outcomes for ships, which had the lowest cost growth.

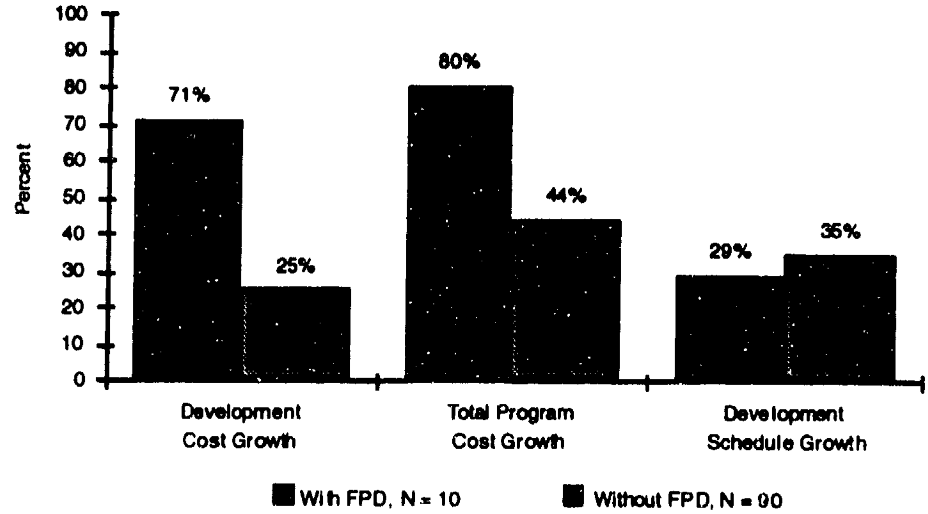


Figure ES-8. Outcomes for Programs With and Without FPD

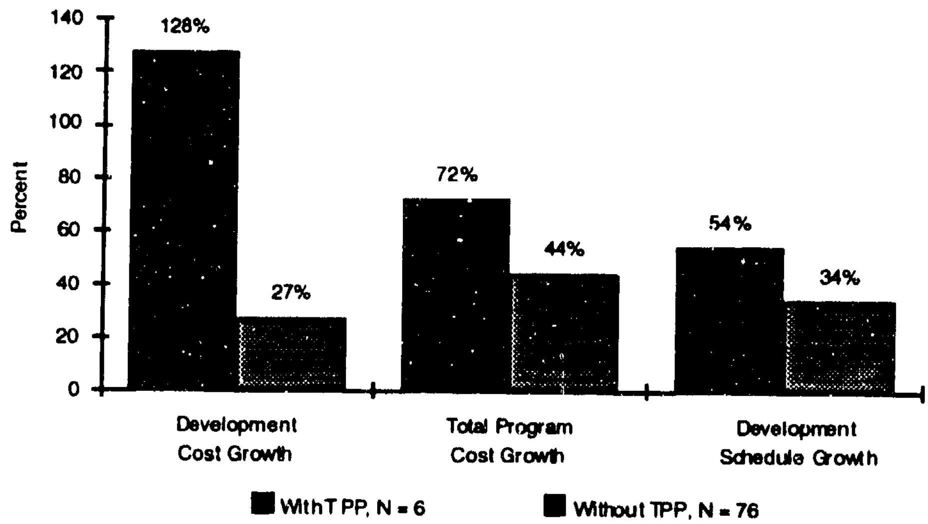


Figure ES-9. Outcomes for Programs With and Without TPP

When making decisions about future programs, DoD can use the cost and schedule records of past programs of the same equipment type, or programs in the same time period, or programs using similar acquisition strategies.

I. INTRODUCTION TO VOLUME I

A. BACKGROUND AND PROBLEM

The Department of Defense (DoD) faces challenges in the years ahead when making decisions about defense acquisition. The Soviet threat is much smaller than it once was, and a major land war in Europe is unlikely. With the breakup of the Soviet Union, the need for the United States to have the latest technology in strategic systems is less urgent. As a counterbalancing force, the United States now faces weaker but more volatile and diffuse threats rather than a single major threat.

As a result of these changes in the threat, the Defense Department expects to receive less funding in real terms for future weapon systems. At the same time, the desire for leading-edge technology has pushed the cost of systems higher. Thus, it is more important than ever that programs to acquire systems be carefully designed and managed. The results of past programs hold lessons for the future.

How well have past systems adhered to their cost and schedule plans? Has the institutionalization of the acquisition process helped or hurt? Have there been some times in history when things turned out better, or are problems inevitable? What are the causes of cost overruns and schedule slippages? What management strategies have been most successful? What kinds of systems are most likely to have trouble, and why? What can the Defense Department do to improve program outcomes?

The answers to questions such as these would help DoD make wise decisions when contracting for future acquisitions.

B. OBJECTIVES

To answer these questions, we developed the following objectives:

- Present patterns of cost and schedule expectations and outcomes for a large group of major programs, including ships and vehicles;
- Choose a set of specific management initiatives applied to acquisition programs, and describe their impact on cost and schedule expectations and outcomes; and

- Assess the effectiveness of management initiatives and provide recommendations.

C. APPROACH

This study builds on work done for a prior IDA study on effective initiatives in acquiring major systems [1].[1] In this study, we build on the database created for that study by providing an additional two years of data and adding ships and vehicles to the database for the first time.

The approach we took to attain our objectives included the following steps:

- Select a set of ship and vehicle programs to add to the acquisition database,
- Collect data on cost and schedule outcomes for ship and vehicle programs, and update the other programs to match,
- Gather information on the management initiatives applied to the programs,
- Analyze trends in cost and schedule outcomes, and
- Assess the effectiveness of management initiatives in minimizing cost and schedule growth.

In defining program outcomes for the study, we focused on cost and schedule outcomes rather than on technical performance. Clearly, the ultimate test of a system is its performance in the field. Operation Desert Storm was a case in point. While there were some problems, U.S. technology generally worked well. The goals that are most often not achieved are cost and schedule, and we focus our attention there.

D. OUTLINE OF REPORT

Section II gives a historical overview of defense acquisition policy. In Section III, the data and outcome measures used in the study are described. Section IV discusses trends in acquisition program cost and schedule outcomes. Sections V through X deal with the individual management initiatives. Finally, Section XI presents conclusions and offers recommendations.

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1 References, listed at the end of this volume, are referred to by number in brackets.

II. BACKGROUND AND ISSUES

A. THE DEFENSE ACQUISITION PROCESS

Systems acquisition in the DoD encompasses the development and procurement of weapon systems for national defense. Acquisition may involve, as it did early in the post-World War II period, the selection of a production model from several prototypes and purchase of off-the-shelf articles. Alternatively, it is common to have a long process of development before production. Development includes early conceptual and validation efforts as well as later engineering and manufacturing development. Today, development can take over 10 years.

Based on administration policies, the Department of Defense develops its method for accomplishing national security policy objectives. DoD assesses the capabilities of existing forces and the resources available for defense in the context of current and prospective threats. From this information, it develops operational requirements and translates those requirements into operating forces. The output of this process is a set of operational requirements for expansion, modernization, and support of military forces. These requirements are translated into systems that are acquired through a military service or defense agency program, following a specific acquisition strategy.

Program offices are established within DoD to refine program requirements, to develop and acquire weapon systems, and to integrate them into operational forces. Military service or agency program managers preside over the process within DoD. They are responsible for interaction with their superiors and with the Defense Acquisition Board (DAB) and the Planning, Programming, and Budgeting System (PPBS). The programs are monitored by the Office of the Secretary of Defense (OSD) and military service management.

B. ERAS IN DEFENSE ACQUISITION

In this study, we want to determine whether outcomes are getting better or whether cost and schedule growth are persistent problems. We discuss four time periods: the 1960s, the early 1970s, the late 1970s, and the 1980s. These represent different eras in defense acquisition. Nelson and Tyson [2] give a fuller historical perspective of defense acquisition.

During the 1960s, Secretary of Defense Robert McNamara introduced mechanisms for planning defense acquisitions. He initiated the PPBS and the Five-Year Defense Program. Systems analysis was a method of using paper studies and simulations to choose among alternative technologies using the framework of cost-effectiveness analysis. Management became centralized within OSD rather than diffused among the military services. Concurrency in development and production was often used in an effort to speed the process. The presumption was that properly planned programs would proceed smoothly. After 1965, the total package procurement (TPP) concept was used in an effort to reduce the government's cost risks. TPP required contractors to bid on the development, production, and support work under one contract. It was designed to thwart contractors from estimating low costs for development (when there was competition) and then "getting rich" on sole-source productions. The Selected Acquisition Reporting system was introduced in 1968 to summarize cost, schedule, and performance data on major systems.

During the early 1970s, there was a negative reaction to the total package concept. A number of total package programs had large cost overruns, and some contractors had to be bailed out. Total package procurement was discontinued in favor of cost-plus-incentive-fee contracts. Deputy Secretary of Defense David Packard urged doing away with concurrency. A more cautious, phased process under which programs had to pass "milestone" tests before they could move on to the next phase was established through the Defense Systems Acquisition Review Council (DSARC). Prototyping, testing using actual hardware rather than paper studies, became more prevalent. More responsibility for day-to-day management of programs was delegated to professional program managers. The Cost Analysis Improvement Group was set up in 1972 to establish uniform criteria for DoD Cost estimates and to support the DSARC by reviewing the military services' cost estimates. DoD instituted the design-to-cost initiative to encourage knowledgeable cost-performance tradeoffs in acquisition.

During the late 1970s, congressional management of the acquisition process greatly increased. In addition, there was growing concern about resource constraints. Extremely high inflation meant that budgets that were planned to cover reasonable price increases ended up buying considerably less than expected. Program stretchouts became a common practice. Rather than canceling programs for which substantial investments had been made in development, Congress made moderate cuts and stretched out production. This had the effect of increasing unit costs.

During the 1980s, a major buildup in acquisition began and many new starts were designed to exploit new technologies rapidly. The Acquisition Improvement Program (the so-called Carlucci initiatives after Deputy Secretary of Defense, Frank C. Carlucci) was a 31-point plan to improve the acquisition process. These points can be grouped into five areas: improve general management principles, increase program stability, improve forecasting and information, improve support and readiness, and reduce bureaucracy. Congress later added a 32nd initiative calling for increased competition. Dual-sourcing of major systems and subsystems was encouraged, and greater emphasis was placed on operational test and evaluation. Two conflicting concerns gained prominence in the 1980s, a sense that fraud, waste, and abuse needed to be attacked with additional auditing and regulation, along with the concern that the regulatory and administrative burden on contractors was contributing to high costs.

Since the 1980s, the breakup of the Soviet Union has resulted in more changes to acquisition. The early stages of weapon system development are being given higher priority and being managed more aggressively. An expanded DoD science and technology program will allow the best technologies to be validated through the construction of advanced technology demonstrators. Still, keeping systems in this pre-Milestone I holding zone allows them to escape the scrutiny given to systems designated as "major."

Three major cycles in the DoD's organization have emerged since World War II:

- ***Centralization and decentralization of broad DoD decision making.*** In both the Truman and Eisenhower administrations, the tendency was toward centralization of functions and away from the decision making power of the services. These steps were cautious at first—in the Truman administration, the idea of having an umbrella organization over the services was new. During the Eisenhower administration, the Secretary of Defense got the power to hire and fire staff. The Kennedy-Johnson administration further consolidated power within the Secretary's office by introducing PPBS and systems analysis. Up to that point, overall DoD organization was following a trend toward centralization. During the Nixon and Ford administrations, some power was given back to the services. There was a move to push decision power further down the chain. The Carter administration moved back toward centralization. Then the Reagan administration moved to decentralize some authority.
- ***Centralization and decentralization of acquisition decision making between OSD and the services and differentiation of the bureaucracy within OSD.*** Until the Eisenhower administration, the services basically did their own procurement. Then an acquisition bureaucracy at the OSD level began to evolve. Acquisition evolved from a simple buy/no

buy decision to a two-phase process—development and production. The creation of the post of Director of Defense Research and Engineering (DDR&E) in 1959 resulted in further differentiation of the OSD bureaucracy. During the Nixon administration, Packard tried to bring parties together with the DSARC process. The DDR&E gradually became stronger and gained status during the Carter administration by being upgraded to an under secretary (USDRE) and being designated as the Defense Acquisition Executive (DAE). The Reagan administration broke up this package by strengthening the Acquisition and Logistics Office, which then vied with USDRE for status as the chief acquisition office—a dispute that was eventually settled when Deputy Secretary Taft assumed the role of DAE. The Packard Commission's recommendations included the establishment of an acquisition "czar" to oversee the entire process, an attempt to put everything back together again. The appointees to this position [the Under Secretary of Defense (Acquisition)] have had to work hard to exercise the authority granted to them.

- ***Upgrading and downgrading of systems analysis since Secretary McNamara.*** Republican administrations have tended to downgrade the level of the systems analysis function to a directorate, while Democratic administrations have tended to raise it to the level of assistant secretary. This office was an assistant secretaryship under McNamara, was downgraded to a director under Nixon, upgraded to an assistant secretary under Carter, downgraded to a director under Reagan, then upgraded late in the Reagan and Bush administrations. This office tended to challenge programs submitted by the military services, so upgrading its status implied less authority for the military services and downgrading it implied more.

While these cycles in acquisition are important, the overwhelming trend over the 40-year period has been toward *standardization and institutionalization of the acquisition process*. During the immediate post-war period, there was little standardization of the acquisition process. Because of the perceived threat, many programs were fast-tracked. By the end of the 1950s, in order to start a program, advocates had to justify it through a development concept paper (DCP) in a standard format. During the 1960s, the acquisition process became more institutionalized. The PPBS and systems analysis also involved more hurdles for a program to get through. The Nixon administration brought increased codification of acquisition regulations. The Packard initiatives included more emphasis on prototyping and more autonomy for the services in the execution process. During the Carter administration, the key development was more detailed resource allocation from the Defense Resources Board. During Reagan's administration, a key initiative was the campaign against fraud, waste, and abuse.

C. RECOMMENDATIONS FOR REFORM

Since the beginning of DoD, many studies have been done by panels, commissions, and other bodies on how major systems ought to be acquired and on related issues such as the organization of the DoD. These bodies can play several different roles. First, they can be catalysts for change. For example, the 1972 Commission on Government Procurement resulted in the development of Circular A-109, which codified acquisition policy for the entire federal government. Panels and commissions can also ratify change that has already happened. For example, the 1970 Fitzhugh Commission recommended that there be no more total package procurement, when, in fact, the government had already decided against it. They can also be used to enhance the visibility of change that has already occurred. Finally, they can be an important safety valve. When officials want to appear to be responsive to a problem, they appoint a commission to study it. As part of our research, we reviewed the recommendations of as many of these commissions, panels, and studies as we could find. We also used a summary of the recommendations of 25 of the most important studies [3]. The eight major bodies we examined were:

- The First Hoover Commission, 1949 [4],
- The Rockefeller Commission, 1953 [5],
- The Second Hoover Commission, 1955 [6],
- The Blue Ribbon Defense Panel (the Fitzhugh Commission), 1970 [7],
- The Commission on Government Procurement, 1972 [8],
- The Defense Resource Management Study, 1979 [9],
- The Grace Commission (President's Private Sector Survey on Cost Control), 1984 [10], and
- The Packard Commission (Blue Ribbon Commission on Defense Management), 1986 [11].

The principal issues studied by these and other panels were organizational responsibility for acquisition within DoD and acquisition strategies and techniques. A common feature of commissions and panels is the tendency to identify a particular problem and then recommend an office be established to oversee or solve it. Thus, organizational responsibility for acquisition has changed over the years.

Some recommendations come up repeatedly. For example:

- Multi-year contracting was recommended by five different groups (the Symington report of 1960 [12], the Office of Federal Procurement Policy (OFPP) study of 1982 [13], the Defense Science Board (DSB) study of 1983

[14], the Grace Commission of 1984 [10], and the Packard Commission of 1986 [11]).

- Limiting the number of programs to those that can be funded was recommended by four panels (the Acquisition Advisory Group in 1975 [15], the Acquisition Cycle Task Force in 1978 [16], the Affordable Acquisition Approach study in 1983 [17], and the Grace Commission in 1984 [10]).
- Simplification of the process was a common theme in many recommendations (the Grace Commission recommended that contract clauses, the regulatory system, specifications, and contracting in general be simplified [10]; the OFPP study in 1982 recommended that simplified procedures for commercial procurement be developed and that procedures for small purchases be simplified [13]; and the Acquisition Cycle Task Force in 1978 recommended shortening the front end of the acquisition cycle [16]).
- Four separate studies recommended that a positive career path be established for program managers (the Fitzhugh Commission in 1970 [7], a RAND study of the 1970s experience [18], the DSB in 1983 [14], and the Grace Commission in 1984 [10]).

On the other hand, some recommendations regarding acquisition strategy have varied. During the 1970s and 1980s, a flurry of recommendations were made promoting increased competition. Other recommendations include preplanned product improvement, better cost analysis and early warning systems for cost growth and schedule slippage, independent subsystem development, and improved planning tools. In addition, many recommendations have been made relating to overstated requirements, unnecessary regulations, improving technology, operational test and evaluation, unnecessary bureaucratic layers, program strategy, and resource planning.

The following summarizes recommendations with respect to the initiatives:

- MYP was recommended frequently, as previously discussed.
- Competition (dual-sourcing) was recommended by the Grace Commission. Increased commercial-style competition was recommended by the Packard Commission. The Acquisition Cycle Task Force study and RAND [18] called for considering competition in all phases of the acquisition cycles.
- Prototyping was one of the Packard initiatives and was recommended by the Packard Commission.
- Design-to-cost was a Packard initiative, but was not explicitly addressed by any of the groups.
- Total package procurement should be prohibited, according to the Fitzhugh Commission.
- Incentive contracting was not fully addressed by any of the groups.

D. ASSESSING OUTCOMES AND THE EFFECTIVENESS OF INITIATIVES

In at least one sense, one can conclude that the acquisition process has been successful: the territory of the United States has not been attacked since World War II, and the deterrent effect of our weapon systems is certainly at least partially responsible for this.

The emphasis on quantitative assessment of program outcomes began in the McNamara era with the introduction of the SAR and has continued since. The acquisition process has typically been assessed in terms of:

- The achieved functional performance of the system relative to the requirements,
- The meeting of planned development and production schedules, and
- The cost of the system relative to planned cost [18 through 24].

Congress tries to cut program costs, but is subject to pressure from constituents who work in defense-related industries. The temptations for Congress to compromise by trimming a little out of each program rather than canceling whole programs are enormous. Such actions fuel cost growth. To improve the predictability of programs, there have been many attempts to improve the quality and independence of the cost-estimation process. Cost estimators still must contend with changes in requirements, schedules, and technical make-up, as well as economic and quantity changes. Also, it is not easy to quantify the impact of major technological advances on cost.

Development and production schedules have always been a matter of concern. The tendency is to underestimate the schedule initially in order to get a program going. Again, as with cost, technological advance and its impact on schedule are not easy to quantify.

Achieving planned functional performance is the goal typically given highest priority. Systems have generally tended to meet their performance goals [19]. For this study, we concentrated on evaluating cost and schedule outcomes, because cost and schedule appear to pose the most problems for the acquisition system.

We selected six initiatives for analysis:

- *Prototyping* has been practiced in several aircraft programs, in missile programs, and in avionics programs. Prototyping is designed to reduce technical risk by building and testing detailed pieces of hardware early. The analytic issue is whether prototyping results in more predictable costs and schedules.
- *Contract incentives* are frequently used to induce the contractor to reduce costs or to engage in other behavior beneficial to the government. Incentive fee

contracts typically involve a cost target, and the contractor splits savings or additional costs with the government based on actual costs. Award fee contracts are more complex; typically, a list of criteria for the program manager or a review board is used to determine the fee awarded.

- *Multi-year procurement* involves committing the government to a procurement and funding plan for several years, in the hope that contractors will be able to produce at lower cost with a stable plan. The analytic issue is whether the government's commitment and reduced flexibility result in a cheaper system.
- *Design-to-cost* was widely practiced in the 1970s. Design-to-cost involves setting a cost goal very early on, similarly to the way a performance goal is set. Progress toward meeting the cost goal is reported periodically. In this report, we discuss how design-to-cost worked in practice and whether there is any evidence to suggest that it reduced cost growth.
- *Dual-sourcing* has been practiced for years in subsystems and is becoming increasingly popular in major systems, particularly in missile programs and in ships. We define dual-sourcing as two or more sources in production, not the competition of companies for FSD or production contracts, which is fairly routine. Dual-sourcing of major systems often requires a considerable investment in technology transfer and qualification. The analytic issue is whether this cost is recouped in a less expensive total system and whether savings can be sustained over the long term as companies become accustomed to dual-sourcing.
- *Fixed-price development* evolved in the Navy in the early 1980s as a way of forcing contractors to share some of the risk in development. The programs we studied are mostly in the early stages and we do not have final outcomes; however, we were able to examine how fixed-price development is working in practice. As a companion piece to fixed-price development, we consider the historical experience of *total package procurement*, which forced the contractor to share the risk of both development and procurement.

III. ACQUISITION PROGRAM DATA

A. PROGRAMS IN THE SAMPLE

We selected a sample of 116 acquisition programs for analysis. The programs, listed in Table III-1, represent the following categories of equipment:

- Tactical aircraft,
- Electronic aircraft,
- Other aircraft,
- Helicopters,
- Electronics/avionics,
- Strategic missiles,
- Air-launched tactical munitions,
- Surface-launched tactical munitions,
- Vehicles and ground combat equipment,
- Ships, and
- Satellites.

The sample includes acquisitions managed by the Army, Navy, and Air Force and both programs that are considered successful and those that encountered problems that were resolved with varying degrees of success (including cancellation). In order to investigate differences in acquisition program outcomes between new and modified systems, the sample contained both types of programs.

The sample is spread over approximately 32 years when grouped by FSD start. Nearly all programs in the sample are either still in production and in service, or are previous versions of weapon systems that are still in production or in service. For the development analysis, we excluded programs fewer than three years past the start of full-scale development, leaving 100 programs. For the production analysis, we excluded programs with fewer than three years of production experience, leaving 82 programs.

Table III-1. Programs in IDA Database

Tactical Aircraft	Electronic Aircraft	Other Aircraft	Helicopters	Electronics/Avionics	Strategic Missiles
F-14A	E-3A	C-5A[b]	UH-60A/L	ASPJ[a]	ALCM
F-14D[a]	E-4	C-5B[b]	AH-64A	JSTARS[a]	Tomahawk
F-15A/B	EF-111A	FB-111A	OH-58D	JTIDS[a]	Trident II[a]
F-16	S-3A	V-22[a]	CH-47D	LANTIRN	GLCM
F/A-18	E-2C	C-17A[a]	Cheyenne[a]	MLS[c]	ICBM[a]
A-10	E-6A	B-1A[a]		OTH-B	Minuteman II
F-5E	EA-6B	B-1B		TRI-TAC	Minuteman III
AV-8A[b]	LAMPS MK 3	T-45TS[c]		WIS[a]	Peacekeeper
AV-8B	P-3C			ADDS[a]	SRAM
				SINCGARS[c]	SRAM2[c]
				ASAS/ENSCE[a]	
				AEGIS[a]	
				AN/BSY-1[a]	
				AN/BSY-2[c]	

Air-Launched Tactical Munitions	Surface-Launched Tactical Munitions	Vehicles and Ground Combat	Ships	Satellites
Sparrow-E	Copperhead	ARSV[c]	CG-47	DMSP
Sparrow-F	5-inch GP[a]	Bradley FVS	DD-963	NAVSTAR GPS
Sparrow-M	Standard Missile 2	M1 Tank	DDG-51	DSP
Sidewinder-M	Patriot	M60A2	FFG-7	DSCS III
Sidewinder-L	Pershing II	FHTV (PLS)[c]	LHA	
Phoenix-A	Lance	FMTV[c]	LHD-1	
Phoenix-C	Improved Hawk	LAV[c]	LSD-41	
HARM	Dragon	MBT[c]	LSD-41 CARGO[c]	
Harpoon	Shillelagh		SSN-21[a]	
Maverick-A/B	MK 48		SSN-688	
Maverick-D/G	MK 48 ADCAP		SURTASS T-AGOS	
AMRAAM[a]	MK 50[a]		T-AO 187	
Hellfire	M198 Howitzer			
TOW	Stinger-Basic/POST			
TOW2	Stinger-RMP			
Condor	FAADS LOS-F-H[c]			
	FAADS LOS-R[a]			
	MLRS			
	Roland			
	Sgt. York			
	155mm HIP[c]			

Notes: 116 total programs, 82 production and 100 development. See the list of abbreviations at the end of this volume for meanings of abbreviations.
[a] Development only.
[b] Production and total program only.
[c] Minimal data.

Several programs were difficult to classify by equipment type because they could reasonably be put into more than one class. AEGIS, for example, is an electronic system, but also shares important characteristics with the ships.

In this volume of the report, we address the programs in the equipment types as shown in Table III-1. However, in Volume II, we highlight two special groups of programs: ships and related Navy programs, and vehicles and related Army ground combat programs. These programs were selected for special emphasis in this study. In the second volume, the ship electronics programs—AEGIS, AN/BSY-1, and AN/BSY-2—are analyzed with the ships. In fact, their outcomes are more similar to the ships than they are to the other electronics programs, and their production costs are included with the ships. Also in the second volume, several Army ground combat programs—the tactical munitions MLRS, Roland, M-198 howitzer, and the intelligence program ASAS/ENSCE—are analyzed with the vehicles.

B. DATA SOURCES

For each of the programs included in the sample, schedule dates, cost, production quantities, and narrative information were obtained from Selected Acquisition Reports (SARs), and the latest available editions of the Defense Marketing Service (DMS) "Missiles Market Intelligence Reports" [25], *Jane's Weapon Systems 1987-88* [26], *Jane's Armour and Artillery* [27], *Jane's Fighting Ships* [28], the *Interavia* summary of weapons [29], and interviews with program management and contractor personnel. The SARs were used as the primary source of information because they are official government documents.

Development estimates (DEs) of schedules, costs, and quantities, made at Milestone II or at the start of full-scale development, were obtained from the earliest available SAR for each program. (Because some of the acquisition programs predate the 1967 initiation of SARs, their "original" estimates of schedules, costs, and quantities shown in this report may not have been the true original estimates; they may instead be subsequent revisions.) Current estimates (CEs) of schedules, costs, and quantities were obtained from the last year-end SARs for completed programs and from the December 1989 SAR for ongoing programs.

The December 1989 SAR (or the final SAR for completed programs) was the basis for our comparison of current estimates with development estimates. The December SAR is designated the comprehensive annual SAR; it is important because it coincides with the President's budget submission to the Congress. Thus, the services and OSD take care to ensure that the SAR data contained in the December SARs match budget items and the

Future-Years Defense Program (FYDP). Table III-2 is an example of a SAR Milestone schedule, and Table III-3 is an example of a SAR program's acquisition cost estimate.

Table III-2. Example of SAR Schedule Milestones

9. (U) Schedule: a. Milestones	Development Estimate/ Approved Program	Current Estimate
Prototype Seeker Firings	N/A Jan 77	Jan 77
AIM/RIM-7M FSD (DSARC II)	Apr 78/Apr 78	Apr 78
Commence Joint TECHEVAL	Feb 80/N/A	Jun 80
OSD Program Review	Apr 80/N/A	Aug 80
Commence IOT&E	Apr 80/N/A	Jun 81
Approval for Service Use	May 81/N/A	Nov 82
DSARC III	Jun 81/N/A	—
IOC (1st delivery to Fleet)	Jul 81/Jan 83	Jan 83
DNSARC III	–/Nov 82	Nov 82

Source: Reference [30].

Table III-3. Example of SAR Program Acquisition Costs

11. (U) Acquisition Cost (USN/USAF): (Current Estimate in Millions of Dollars)

	Development Estimate (FY 75-85)	Changes	Current Estimate (FY 75-89)
a. (U) Cost			
Development (RDT&E)	54.5	–1.2	53.3
Procurement	859.2	+587.4	1446.3
G, C&A	(681.7)	(+489.3)	(1,171.0)
Propulsion	(46.7)	(+14.0)	(60.7)
Other Hardware	(35.8)	(–13.4)	(22.4)
Procurement	(66.4)	(+19.1)	(85.5)
Total Flyaway	(830.6)	(+509.0)	(1,339.6)
Fleet Support	(19.9)	(+47.5)	(67.4)
Initial Spares	(8.7)	(+20.9)	(29.6)
Construction	—	—	—
Total FY 78 Base Year $	913.7	+576.2	1,489.9
Escalation	344.4	+924.3	1,268.7
Development (RDT&E)	(2.8)	(+5.1)	(7.9)
Procurement	(341.6)	(+919.2)	(1,260.8)
Construction	—	—	—
Total Then-Year $	1,258.1	+1,500.5	2,758.6
b. Quantities			
Development (RDT&E)	44	—	44
Procurement	11,095	+4,497	15,592
Total	11,139	+4,497	15,592
c. Unit Cost			
Procurement:			
FY 78 Base-Year	$.077	+.017	.094
Then-Year	.108	+.069	.177
Program:			
FY 78 Base-Year $	.082	+.015	.097
Then-Year	.113	+.067	.180

Source: Reference [30].

The SARs present cost estimates in escalated dollars as well as in constant dollars. Our analysis used the constant-dollar estimates so that inflation would not distort comparisons among programs whose DEs were established at different times. For programs that were rebaselined, development estimates of development and production costs were obtained by escalating development and production costs at the time of the development estimates to the new base-year dollars using January 7, 1990 DoD deflators.

The SAR is a highly aggregated source of cost information. We would have preferred data sources with more detail, and we did review sources such as the Contractor Cost Data Reporting (CCDR) system. Given the number of programs in our sample and the timeframe in which the effort was to be accomplished, we opted to use the SAR. The SAR is a definitive, standardized source of data with visibility at decision making levels. It has a prescribed format common to all the services and allows for comparisons of cost, schedule, and quantity changes across programs. Development concept papers (DCPs) were reviewed to provide additional cost and schedule information in the programs.

Representatives of selected contractors and program offices provided additional cost and schedule data and answered questions that surfaced during review of the SARs. These interviews greatly enhanced our understanding of individual programs.

Narrative information was obtained on the applicability of various defense acquisition policies and initiatives to each of the programs included in the sample. Information was also obtained where available concerning the nature and extent of any major problems that were encountered, how the problems were managed, and what appeared to be the causes.

C. OUTCOME MEASURES

From the information we gathered, a database was developed to allow examination of program outcomes and to permit analysis of the effectiveness of acquisition initiatives in acquiring major systems. One measure of the outcome of a program is cost growth during development, production, and across the total program. Another indicator of good program performance is the extent to which the system can be developed and produced according to plan. Therefore, we also viewed schedule slippage in development and production as a measure of program outcome. Finally, trends in quantity change give clues to such issues as reasonableness of the development plan, the degree of production stability, and the prevalence of program stretch.

The specific outcome measures produced were as follows:

- Development cost growth (DCG),
- Production cost growth (PCG),
- Total program cost growth (TPCG),
- Development schedule growth (DSG),
- Production schedule growth (PSG),
- Development quantity growth (DQG),
- Production quantity growth (PQG), and
- Stretch.

We use the word "growth" to refer to changes in cost, quantity, and schedule because in most cases the change reflects an increase in dollars, numbers, or time. However, in a few cases (such as when development or production quantities are reduced), "growth" is negative. "Stretch" is a measure of the extent to which production rate (quantity over time) is decreased or stretched.

For each of the measures of program outcomes, we compared the program development estimate to the final (or current) estimate. We defined a program as the first major version of a weapon system. A few major programs maintain the same designator and a consistent set of SARs throughout several versions, the most prominent example is the F-15 aircraft program, which had Milestone II in 1970 and is currently in production for the "E" version. This creates a problem as to which costs to consider. Since our purpose was to evaluate alternative acquisition strategies for major programs, we defined both the cost measures and the strategy measures for the first version of the system, e.g., the F-15A. We did include later versions in the production schedule and quantity data where they were included in the same SAR. The F-14 program has three sets of SARs, the F-14, F-14A/D and F-14D. We developed measures for two programs, the F-14A and F-14D.

As an example of a typical program's profile, we use the Hellfire missile program. Table III-4 shows cost, schedule, and quantity information, extracted principally from the SAR, for the Hellfire program. The development estimate information is from the initial Hellfire SAR of June 1976. The current estimate for the Hellfire program is from the most recent SAR available at the time of this study, the December 1989 SAR. The derivation of "current estimate for development estimate quantity" is described in the next subsection.

Table III-4. Hellfire Program Schedule and Cost Summary

	Development Estimate (6/76)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Milestone II	2/76	2/76	—
Development Start Date	12/72	12/72	—
Development End Date (IOC)	5/83	7/86 (+44%)	—
Development Quantity	241	333 (+38%)	—
Development Cost (M $)	210.3	230.2 (+9%)	—
Milestone III	7/80	3/82	—
Production Start Date	7/80	3/82	—
Production End Date	9/86	9/93	—
Production Quantity	24,600	56,716 (+130%)	24,600
Unit One Cost (K $)	—	—	1,160.0
Slope of Cost-Quantity Curve	—	—	82.1%
Production Cost (M $)	277.9	806.6	475.1
PAUC (K $)	11.30	14.22 (+26%)	19.31 (+71%)
Total Program Cost (M $)	488.2	1,093.2	705.27 (+44%)
Total PAUC (K $)	20.46	19.28 (-1%)	28.67 (+40%)
Years of Actual Data			
Development	Completed		
Production	7		

Notes: All costs are in 1975 dollars. Numbers in parentheses represent percentage change.

A summary of the Hellfire program's outcome is provided in Table III-5. The database for all the programs used in this study is found in Appendix A.

Table III-5. Outcomes for the Hellfire Program

Outcome Measure	Percentage Growth
Development Cost Growth	9
Production Cost Growth[b]	71
Total Program Cost Growth[b]	44
Development Schedule Growth	44
Production Schedule Growth	75
Development Quantity Growth	- 5
Production Quantity Growth[a]	130
Stretch	-26

[a] Based upon the increase from the development estimate quantity to the current estimate quantity.

[b] Based upon the current estimate of the cost of the program quantity contained in the development estimate.

1. Evaluation of Cost Growth

In order to understand outcomes by program phase, we separated cost growth into development and production cost. Since production cost is much higher than development cost, it tends to drive our estimate of total program cost growth. However, development cost growth is also of interest, since it is here that the technical challenges are met.

The techniques applied in our analysis for weapon system cost growth are similar to those used in past investigations of program cost outcomes (for example, see [1 and 19]). The following process was used to produce development cost growth ratios:

- All program cost estimates were collected in the base-year dollars specified for the program. For the Hellfire program example, this is fiscal year 1975 dollars.
- Actual development costs were determined for the period from program startup through initial operational capability (IOC) date, including development costs incurred beyond IOC that are still associated with the original research, development, testing and evaluation (RDT&E) effort. Development costs for major modifications and other changes beyond the scope of the original development effort were excluded.
- The development cost growth (DCG) ratios were calculated by dividing actual development cost by the development cost estimate at Milestone II. For the Hellfire program, this is: $230.2 million divided by $210.3 million, for a development cost growth factor of 1.09. We report the cost growth as a percentage (e.g., development cost growth for Hellfire is 9 percent.)

Before constructing production cost growth ratios, we had to address some additional issues. First, the best information available from the SAR is the annual funding summary that appears in recent SARs. These data represent the price to the government, not strictly the cost of the system for the contractor's point of view. In this effort, "cost growth" ratios refer to the price or cost to the government.

Second, many programs change their planned quantity as the program progresses through production. Therefore, some adjustment to costs is necessary to take quantity change into account. The SARs provide estimates of cost change due to quantity change (and schedule, engineering, inflation, and estimating changes). We did not use these estimates, because we found that program offices interpreted the guidelines for developing these estimates in widely divergent ways. Instead, we developed price-improvement curves from the SAR annual data for completed production years. Price-improvement curves show the relationship between cost and the cumulative number of units. In weapon systems, early units tend to cost the most, while later units cost less, as learning takes place. From these curves, we calculated the cost of the originally planned quantity, the development estimate quantity (DEQ).

In the Hellfire example, procurement quantities changed from 24,600 to 56,716, a 131-percent increase. Production costs increased from $277.9 million to $806.6 million.

Much of this growth in production cost had to be due to more than the doubling of quantities procured and not to cost growth. Using our price-improvement methodology, we estimated actual Hellfire production cost of the originally planned 24,600 missiles as $475.1 million, and calculated a production cost growth of 71 percent.

Several programs examined do not have annual funding detail in the SARs that allow calculation of the current production estimate at the development estimate quantity. When no detailed data were available, the slope of the price-improvement curve was assumed to be 90 percent. The current estimates of production cost and quantity from the SAR were used to estimate first-unit cost and production cost at the development estimate quantity.

IDA estimates of total production costs were then determined by adding the current estimate of development costs to the current estimate of production cost at the development estimate quantity. In the Hellfire program, total program cost at the DEQ is estimated to be $705.27 million. The total program cost growth is then 44 percent.

2. Evaluation of Program Schedules

We also report estimates of schedule slippage in development and production. Systems need to be developed on an appropriate schedule so that they are ready for users when planned. Thus, development schedule growth is an important indicator of program success. Production schedule slippage is more complicated, because it is intertwined with quantity changes. Production schedule growth, with quantity constant, often means that the program is being stretched because of cost growth or because of funding shortages. Production schedule growth, with increased quantity, often means that the program is more successful than anticipated.

Schedule growth during development of a new weapon system is normally measured by the amount of slippage experienced in a program between a fixed base date (e.g., Milestone II date or FSD contract start, whichever is earliest) to its completion. After the necessary data were collected, the development schedule growth (DSG) ratio was computed using the following formula:

$$\text{Development Schedule Growth Ratio} = \frac{\text{Actual Time (Months) from FSD to IOC}}{\text{Estimated Time (Months) from FSD to IOC}}$$

The development schedule growth for Hellfire is 44 percent.

Production schedule growth is determined using the same technique. Production span is defined as the period from Milestone III or first production contract to production end date or the last fiscal year of planned funding. Production schedule growth (PSG) ratios are computed using the following formula:

$$\text{Production Schedule Growth Ratio} = \frac{\text{Actual Time (Months) from Production Start to Production End}}{\text{Estimated Time (Months) from Production Start to Production End}}$$

The Hellfire program has exhibited production schedule growth of 75 percent.

3. Evaluation of Quantity Changes

Both development quantity and production quantity changes were documented using the same technique as described for program schedules, except that quantity is substituted for time. Hellfire experienced -5 percent development quantity growth (DQG). Production quantity growth (PQG) was 130 percent.

We developed another index that measures the extent to which production is stretched. In buying major weapon systems, the government frequently finds that it does not have a large enough budget to buy, say, the 100 systems per year that it had planned. A common way of dealing with this problem is to buy the whole quantity, but at the rate of only, say, 50 per year. To measure this phenomenon, we express the following ratio:

$$\text{Stretch} = \frac{PS_{CE}/PS_{DE}}{PQ_{CE}/PQ_{DE}} .$$

The Hellfire program experienced a stretch of -26 percent. Systems were acquired relatively quickly.

IV. PATTERNS IN ACQUISITION PROGRAM OUTCOMES

A. INTRODUCTION

This section presents results from the database. Aggregate outcomes are presented, and differences by time period, equipment type, program phase, and development program type (new vs. modification) are identified and discussed. Table IV-1 shows selected results from the IDA database.

Table IV-1. Statistics on Key Variables

Outcome Measure	Number of Programs	Mean Unweighted	Mean CE Weights	Mean DE Weights
Development Cost Growth (DCG)	100	45%	29%	13%
Production Cost Growth (PCG)	82	58%	56%	32%
Total Program Cost Growth (TPCG)	82	50%	47%	29%
Development Schedule Growth (DSG)	100	34%	—	—
Production Schedule Growth (PSG)	77	57%	—	—
Development Quantity Growth (DQG)	98	10%	—	—
Production Quantity Growth (PQG)	82	34%	—	—
Stretch	76	67%	—	—

On average, unweighted program cost grew 50 percent over planned, 45 percent in development and 58 percent in production. Development schedules, an important indicator of on-time performance, grew by about one-third. In full-scale development, programs had to build only 10 percent more systems than planned. Production schedules grew by 57 percent, but this was largely explained by a 34 percent increase in production quantity. We found that stretch was a more useful measure of production schedule and quantity growth; therefore, we use stretch instead of PSG and PQG in the remainder of the paper.

Note that cost growth means are shown unweighted and weighted by two measures of program size, the current estimate and the development estimate. Weighting makes a considerable difference in average cost growth magnitudes. Average total program cost growth is 47 percent using CE weights and 29 percent using DE weights. In this section, we show key cost outcomes using both types of weights. In later chapters, we identify those instances in which weighting makes a difference in the direction of a result. A discussion of weighting issues is contained in Appendix B.

B. OUTCOMES BY TIME PERIOD

As previously discussed, the purpose of analyzing outcomes by time period is to see whether broad program policy in specific time periods influenced acquisition outcomes. The time periods analyzed are the 1960s, the early 1970s, the late 1970s, and the 1980s.

Each of these periods had different acquisition policies and initiatives. In the 1960s, the idea of program management using a structured milestone process was just beginning. Initiatives used included total package procurement and concurrency. Management was centralized within OSD. In the early 1970s, the prevalent initiatives, with the influence of Deputy Secretary of Defense David Packard, included incentive contracting, prototyping, and design-to-cost. In the late 1970s, design-to-cost became institutionalized, and experiments with dual-sourcing in tactical munitions were tried. In the 1980s, initiatives included fixed-price development, multi-year procurement, and more dual-sourcing.

We grouped programs into time periods according to their FSD starts, because FSD is a major milestone and acquisition strategies are often determined by that point. Therefore, it seems reasonable to conclude that policies at the time of FSD have the most influence on a program. However, a typical program continues for over ten years past FSD, so it may be influenced by the policies of other periods as well.

We compare observed results in terms of cost and schedule with estimates at the time of full-scale development. Table IV-2 shows cost, schedule, and quantity outcomes by time period.

Table IV-2. Summary of Outcomes by Time Period (Percent)

Outcome Measure	1960s	Early 1970s	Late 1970s	1980s
DCG	40 (25)	31 (17)	23 (32)	26 (26)
PCG	78 (24)	45 (17)	63 (31)	-4 (10)
TPCG	61 (24)	42 (17)	52 (31)	-1 (10)
DSG	50 (25)	25 (17)	28 (32)	32 (26)
DQG	17 (25)	26 (17)	0 (31)	5 (25)
Stretch	111 (19)	54 (16)	62 (31)	18 (10)

Notes: Cost growth figures are weighted by the current estimate. Numbers in parentheses are numbers of programs.

The 1960s, when SAR cost estimation was in its infancy, was a period of high cost growth. Major programs such as the C-5A aircraft and the Minuteman missile were being developed. In addition, methods of tracking and managing programs were less highly structured than today [31]. The cost growth in the 1960s was higher than in later periods. Production cost growth and total program cost growth were significantly higher. Development schedule growth was also higher in the 1960s than in later periods.

Programs with FSD start in the early 1970s, the time of the Packard initiatives, had good overall records. Cost growth in production was relatively low; however, the number of programs started in this time period was also relatively low.

Programs with FSD starts in the late 1970s did not fare as well (in terms of cost growth) as those that began in the early 1970s. Their overall cost growth was 52 percent, nearly as high as the 1960s high of 61 percent. Programs did well in development cost (23 percent growth), but less well in production. While they generally did well in terms of meeting their development schedules, programs were likely to be stretched in production. This contributed to the unfavorable cost outcomes.

The jury is still out on programs begun in the 1980s. Mean development cost growth was 26 percent, as high as the late 1970s. However, total program cost growth is -1 percent, and this is significantly lower than in the past (significance level = .05).

Since cost growth tends to accumulate over time, we expect that this figure will climb with increased experience. The tendency is for contractors to underestimate costs initially. As the program progresses, however, program managers are forced to request additional funds. Thus, cost growth increases as experience increases. We see some evidence of this worsening trend by comparing the results here with those from an earlier IDA study based on 1987 data. At that time, average development cost growth was 16 percent, as compared to 26 percent now. Moreover, total program cost growth was -8 percent, versus -1 percent now. In addition, development schedule growth, an important indicator of future cost growth, has increased from 21 percent to 32 percent.

Because cost growth accumulates gradually as experience is gained, cost estimates have to be revised to reflect experience. If the end of the production run is more than five years into the future, then cost estimates for the out-years would not appear in the FYDP and might not be revised immediately.

Other caveats about the 1980s programs include:

- The relative need to "sell" a program at a given time may influence the initial development estimate of both cost and schedule. When budgets are fairly generous and expected to increase, as in the early 1980s, obtaining funds is relatively easy, so there is no incentive to underestimate. However, if budgets are tight, there may be an incentive to underestimate costs in order to get the program funded. This would lead to higher cost growth.

- Although the 1980s programs appear to be doing well, they are not very far along. These programs should be reevaluated once more experience has been gained.

C. OUTCOMES BY EQUIPMENT TYPE

The purpose of analyzing outcomes by equipment type is to see whether outcomes are substantially different for the various classes of systems examined. Table IV-3 shows outcomes by equipment type.

Tactical munitions programs experienced the highest total program cost growth (103 percent for surface-launched and 102 percent for air-launched) of any type of system examined. Tactical munitions probably have a higher percentage of technological content than other weapons systems. The guidance and control system usually pushes the state of the art and represents two-thirds to five-sixths of the cost of the total system. Tactical munitions systems are not very glamorous and therefore may not receive as much high-level management attention as needed.

Vehicle programs experienced the next highest cost growth, 96 percent. The average, however, masks a great deal of variability in program outcomes. Additional detail on vehicles and related programs is contained in Volume II.

Experiences with other equipment types generally were much better. Aircraft, satellites, and strategic missiles tended to have lower total program cost growth than tactical munitions.

The lowest total program cost growth for a substantial group was displayed by the ship programs, 15 percent. (Electronics/avionics cost growth, while lower, was based on minimal data.) While development cost growth was not particularly low, 36 percent, ship programs tend to include much of what other programs define as development costs in production, and production costs did not grow by much. Moreover, ship programs tended to procure substantially more quantity (99 percent) than planned. Additional detail on the ship programs is provided in Volume II. Satellites also experienced relatively low total program cost growth, 20 percent. Increased production quantity and multi-year procurement may have played a role in this result.

Table IV-3. Summary of Outcomes by Equipment Type (Percent)

Outcome Measure	Tactical Aircraft	Electronic Aircraft	Other Aircraft	Helicopters	Air-Launched Tactical Munitions	Surface-Launched Tactical Munitions	Electronics/ Avionics	Strategic Missiles	Vehicles	Ships	Satellites
DCG	22 (8)	33 (9)	22 (5)	33 (5)	58 (16)	36 (19)	78 (11)	5 (9)	104 (3)	36 (11)	32 (4)
PCG	25 (8)	31 (9)	48 (4)	51 (4)	130 (15)	124 (15)	14 (3)	50 (7)	93 (3)	14 (11)	18 (4)
TPCG	24 (8)	30 (9)	38 (4)	42 (4)	102 (15)	103 (15)	10 (3)	35 (7)	96 (3)	15 (10)	20 (4)
DSG	5 (8)	20 (9)	15 (5)	16 (5)	66 (16)	32 (19)	47 (11)	31 (9)	78 (3)	22 (11)	31 (4)
DQG	9 (8)	30 (9)	-5 (4)	-7 (5)	44 (16)	-4 (19)	21 (10)	-20 (9)	13 (3)	0 (11)	0 (4)
Stretch	48 (7)	41 (9)	18 (3)	32 (4)	98 (14)	144 (15)	57 (3)	94 (4)	-29 (3)	24 (10)	-7 (4)

Notes: Numbers in parentheses are numbers of programs. Cost growth figures are weighted by the current estimate.

[a] Condor (stretch = 5,600) was excluded from the calculations.

Vehicles had the highest development cost growth, 104 percent, but we had only three data points. Electronics/avionics programs, which exhibited the next highest cost growth in development, 78 percent, were examined only for development cost growth because we could not disaggregate production costs from the SARs. However, the rationale that applies to the history of cost growth for munitions programs very likely applies to electronics programs as well. Strategic missiles (5 percent) had the lowest development cost growth.

Development schedule growth, as measured by Milestone II to IOC actual versus planned, was highest for air-launched tactical munitions and vehicles programs (both at 66 percent). Tactical aircraft exhibited the least development schedule growth (5 percent). Overall, aircraft had significantly lower development schedule growth, and tactical munitions significantly higher DSG, than the overall sample of programs.

D. OUTCOMES BY PROGRAM PHASE

We examined cost growth in development and in production separately (as shown in Tables IV-1 through IV-3). From Table IV-1, we can see that cost growth is less on average in development than in production. This may be because there is less time between the estimate and the actuals in development—by the time production is completed, by contrast, the development estimate may be 15 years old or more. Moreover, the development budget (typically represented by the RDT&E budget line item) is limited, and development activities that cannot be finished by the time this budget is spent may have to be financed under the production line item, thus increasing production cost growth.

However, for several equipment types (Table IV-3), development cost growth is greater than production cost growth. These include electronic aircraft (33 versus 31 percent), vehicles (104 versus 93 percent), ships (36 versus 14 percent), and satellites (32 versus 18 percent). (Again, we regard the low production cost growth in electronics/avionics as an accounting anomaly.) The difference for electronic aircraft is small, and, for ships, development costs are a small proportion of the total. Therefore, the two most interesting cases are the vehicles and the satellites. Vehicles tend to suffer from problems of definition, and this would tend to increase cost growth in development. Satellites are often technically sophisticated, which would tend to increase development cost risk, and multi-year procurement may have helped to hold down production cost growth.

E. OUTCOMES BY DEVELOPMENT PROGRAM TYPE

Finally, we analyzed program outcomes for both new development programs and modification programs. The purpose of this analysis was to see whether outcomes are substantially different between new and modification programs. Table IV-4 shows outcomes for new and modification programs. Table IV-5 shows additional detail by equipment type.

Table IV-4. Summary of Outcomes by Program Type (Percent)

Outcome Measure	New Programs	Modification Programs
DCG (CE)	33 (70)	20 (30)
DCG (DE)	14 (70)	10 (30)
PCG (CE)	71 (55)	23 (27)
PCG (DE)	44 (55)	12 (27)
TPCG (CE)	59 (55)	20 (27)
TPCG (DE)	37 (55)	14 (27)
DSG	34 (70)	36 (30)
DQG	2 (68)	27 (30)
Stretch	75 (51)	50 (25)

Notes: Numbers in parentheses are numbers of programs. Cost growth figures are weighted by the current estimate.

We would expect that modification programs would have lower technical risk and thus less cost and schedule growth. This is generally the case in the aggregate for some equipment types; however, some modification programs exhibit as much or more development cost growth as new ones. This is true for tactical and electronic aircraft and particularly for air-launched tactical munitions (156 percent DCG for modifications versus 31 percent for new). For these types of programs, apparently technical risk is underestimated for the modification programs. Other programs show patterns more like what we would expect, with cost growth lower for modifications.

In the aggregate, we saw little difference in development schedule growth between new and modification programs. When we disaggregated by equipment type, development schedule growth was much as we would expect—modification programs were more likely to meet their schedule goals, or to overrun them by less, than new programs. The major exception is vehicles, where the one modification program, the M60A2, overran its schedule by 217 percent. Surprisingly, modification programs had higher development quanitity growth, largely due to the air-launched tactical munitions.

Table IV-5. Summary of Outcomes by Equipment and Program Type (Percent)

Equipment Type	Program Type	DCG	PCG	TPCG	DSG	DQG	Stretch
Tactical Aircraft	New (7)	21 (6)	28 (7)	27 (7)	6 (6)	12 (6)	43 (6)
	Modification (2)	27 (2)	-14 (1)	-8 (1)	1 (2)	0 (2)	79 (1)
Electronic Aircraft	New (6)	28 (6)	31 (6)	28 (6)	22 (6)	28 (6)	81 (6)
	Modification (3)	56 (3)	29 (3)	35 (3)	15 (3)	33 (3)	-39 (3)
Other Aircraft	New (6)	23 (4)	102 (2)	79 (2)	19 (4)	-7 (3)	80 (1)
	Modification (2)	17 (1)	-8 (2)	-6 (2)	0 (1)	0 (1)	-13 (2)
Helicopters	New (4)	33 (4)	54 (3)	44 (3)	18 (4)	-9 (4)	38 (3)
	Modification (1)	13 (1)	34 (1)	32 (1)	6 (1)	0 (1)	14 (1)
Air-Launched Tactical Munitions	New (8)	32 (8)	206 (7)	149 (7)	67 (8)	-6 (8)	61 (6[a])
	Modification (8)	156 (8)	37 (8)	40 (8	65 (8)	93 (8)	169 (8)
Surface-Launched Tactical Munitions	New (14)	39 (14)	147 (11)	123 (11)	36 (14)	-7 (14)	169 (11)
	Modification (5)	27 (5)	49 (4)	37 (4)	21 (5)	6 (5)	73 (4)
Electronics/Avionics	New (10)	82 (10)	14 (3)	10 (3)	47 (10)	23 (9)	57 (3)
	Modification (1)	49 (1)	—	—	49 (1)	0 (1)	—
Strategic Missiles	New (4)	6 (4)	46 (3)	35 (3)	34 (4)	-29 (4)	187 (2)
	Modification (5)	4 (5)	53 (4)	35 (4)	28 (5)	-12 (5)	0 (2)
Vehicles	New (3)	106 (2)	88 (2)	93 (3)	8 (2)	20 (2)	-44 (2)
	Modification (1)	28 (1)	121 (1)	115 (1)	217 (1)	0 (1)	-1 (1)
Ships	New (8)	37 (8)	24 (7)	24 (7)	30 (8)	0 (8)	36 (7)
	Modification (3)	16 (3)	-6 (3)	-6 (3)	1 (3)	0 (3)	-3 (3)
Satellites	New (4)	32 (4)	18 (4)	20 (4)	31 (4)	0 (4)	-7 (4)
	Modification (0)	—	—	—	—	—	—

Note: Cost growth figures are weighted by the current estimate. Numbers in parentheses are numbers of programs.

[a] Condor (stretch = 5,600) omitted from the calculations.

With respect to production and total program costs, modification programs generally exhibited less cost growth than new programs. There are, however, two interesting exceptions. Electronic aircraft modification programs had higher overall cost growth than new ones, possibly because of technical risk. Recall that electronics and avionics programs, a big part of electronic aircraft, had the highest development cost growth. In addition, the effort required to integrate the electronic equipment with the rest of the aircraft is often underestimated. The second exception is vehicles, which are frequently subject to considerable change in technical requirements. With only three vehicles in the database, however, it is difficult to draw a conclusion.

F. CONCLUSIONS

There is little indication that acquisition program outcomes are getting either substantially better or substantially worse. Development schedule growth and cost growth in development, production, and the total program remain persistent problems, even though considerable improvements have been made in the information available to program managers. The early 1970s, the time of the Packard initiatives, seemed to have better program outcomes than the 1960s, which had poor outcomes.

Our conclusions about programs begun in the 1980s are preliminary. While many programs were begun in the 1980s, there is still relatively little production experience to judge how they have fared. Development cost growth so far is slightly better than past experience, while development schedule growth is typical of past experience. Production outcomes look substantially better than in the past. However, we are reluctant to draw any conclusions about the production phase because of the small number of programs in our sample and because those programs are mostly in the early stages of production.

Program outcomes differ depending on equipment type. Tactical munitions and vehicle programs experienced the highest total program cost growth. This was foreshadowed by their cost and schedule problems in development. Ship programs had the lowest total program cost growth.

Vehicle programs and electronics programs had the highest development cost growth of any equipment type. (We were unable to track substantial production experience of electronics/avionics systems due to data limitations—production data is usually included in the platform SARs and cannot be disaggregated.) We have seen that problems in development tend to be followed by production problems. This, coupled with the fact that many future programs emphasize electronics heavily, suggests that these programs should be targeted for increased management attention.

As expected, modification programs exhibited lower total program cost than new programs. It is easier to stay on plan for a modification program. However, there are two equipment types for which this was not the case—vehicles and electronic aircraft.

V. PROTOTYPING

A. BACKGROUND

Prototyping has been practiced in some form or other throughout the history of acquisition. There has always been a need to test new types of equipment before any large-scale application. Since the end of World War II and the advent of the systems management approach to defense weapons acquisition, prototyping has become a more prominent part of the process. During this period, it has experienced cycles of popularity and disfavor.

The extent of prototyping is roughly counter-cyclical with the DoD budget. When the budget is ample, there is little prototyping, and when the budget is tight, there is more. For example, there was considerable prototyping in the periods of build-down after the Second World War and the Korean War. During the early 1960s, there was little prototyping, as the Kennedy administration believed that systems analyses could take the place of prototypes. Less than a third of major systems were prototyped. In the early 1970s, Deputy Secretary of Defense David A. Packard emphasized the importance of prototyping in a fly-before-buy strategy. Around half of major systems were prototyped during this period. During the early 1980s, when the Reagan buildup occurred, once again the defense budget increased relative to GNP, and there was less prototyping. The Packard Commission report in 1986 again called for more prototyping. Recently, the emphasis has been on prototyping using advanced technology demonstrators to use resources more efficiently.

Consideration of prototyping is especially timely now for a number of reasons:

1. A decreasing real defense budget increases pressure on weapon system developers to make their programs more predictable and financially viable. Prototyping can provide these benefits.
2. As a consequence of lower overall budgets, less funding is available for major acquisition programs. Prototyping two systems is often cheaper than buying one.
3. Fewer new starts are expected in this lower defense budget climate. The few new programs that are funded are likely to carry a great deal of technical risk and to push the state of the art. Since chances to win a bid are becoming

increasingly rare, there is a great deal of pressure to underestimate cost and schedule. Prototyping encourages realism in technology, cost, and schedule.

4. The ability of the government and contractors to sustain the defense technology base is in question. If not enough work is forthcoming from the DoD, then manufacturers will leave the industry. More importantly, new ideas will not be forthcoming from the technology base, and design teams will wither away. Ben Rich, head of Lockheed's Advanced Development Projects said, "Kelly Johnson [his predecessor] developed 47 different airplanes in his 50 years. In my 40 years, I developed 27 different airplanes. My young engineer today is going to be lucky to see one project—an ATF." [32] Prototyping can help to keep design teams together.

5. Threats to national security are changing as a result of the changes in Eastern Europe, and they are much more difficult to predict.

6. Technical sophistication is increasing. More sophisticated equipment carries even higher technical risk and risks of cost and schedule growth. Integration is becoming more complicated. Software costs are becoming a major part of system costs, and software projects have been difficult in the past. Making the transition from design to production is also a major concern, particularly if early research and development on manufacturing technologies are not addressed by the defense industry.

The evidence on prototyping from the literature consists mainly of case studies and qualitative observations. This section addresses the issue of prototyping using quantitative evidence where available for prototype and non-prototype programs. It draws from prior IDA work [33 through 36].

As defined in this study, prototyping refers to the construction and testing of working models created to demonstrate specific design or operational objectives in advanced development (but not in concept exploration), e.g., before engineering and manufacturing development (EMD) at Milestone II. Our definition does not include EMD test articles.

The primary objective of any prototype program is to obtain information to reduce the uncertainty and risk concerning the design concept, cost, or usefulness of a particular model before committing to the greater expense of EMD. Historically, a decision to go into EMD virtually ensures that the system will go on to production.

If an acquisition program is to be successful, potential design problems need to be identified and resolved as early as possible. Such problems can affect the performance and technical characteristics of the weapon, its development schedule, and its development, production, and support costs.

The primary purpose of prototyping is to reduce technical risk. Prototypes can be used to answer three technical questions. The three questions, which are not mutually exclusive, are:

- Is the concept feasible?—Proof of Concept
- Does the design work the way it is supposed to work?—Proof of Design
- Does the system provide a militarily useful capability?—Proof of Mission Suitability

B. BENEFITS AND WEAKNESSES

A key benefit of prototyping is early information—both qualitative and quantitative. Before committing to EMD, the government determines whether or not a design can meet the objectives specified for it through prototyping. For example, can a vertical takeoff and landing (VTOL) aircraft hover in controlled flight? Does the guidance system work? Either a positive or a negative answer can be worthwhile. If the system does not work, the designers can avoid committing to a fruitless path during EMD, when much greater levels of resources are committed and expended.

Competitive prototyping can also be very useful in source selection. The government may make a better choice of contractor by evaluating testable hardware rather than just paper studies. If there is a teaming arrangement, prototyping allows the government to see whether or not contractor teams mesh well and allows anticipation of any integration problems.

Quantitative information from prototyping includes performance, schedule, and cost dimensions. Required performance characteristics can be validated through the testing of a prototype, or the requirements can be changed to fit what can reasonably be achieved. Acquisition managers can also make more credible estimates of how long a program will take and how much it is likely to cost.

All of the information gained from prototyping may result in lower costs for development and production and shorter time in EMD than for non-prototyped systems.

In general, weaknesses of prototyping include the additional resources and time needed to accomplish a prototype prior to EMD start. The cost of the prototyping phase is an upfront cost, and there is often considerable resistance to committing the funds. The YF-16 prototype cost on the order of $100 million in a $30 billion program; the A-10, about $100 million in a $5 billion program, and the AV-8B, $150 million for a $10 billion program. The cost ranges less than 2 percent of the total program. This seems to be the range for other types of equipment as well.

It is not clear that prototyping increases program costs above what they would have been without a prototype. Without prototyping, costs might grow even more as problems crop up later in the program, when spending rates are high. We examine some evidence here.

Prototyping may result in some increase in time to achieve initial operating capability (IOC). Prototyping involves building and testing hardware at an early stage. Some program officials complain that prototyping slows down the momentum of the program.

Prototyping might be overkill when the information to be gained is not all that important to the accomplishment of the program. This can be a difficult decision. One example here is the aircraft nuclear propulsion program in the 1950s. The uncertainty had to do with the aircraft nuclear reactor performance, weight, and cost. However, a great deal of time and money went into building the large turbine engine that was going to be driven by the nuclear reactor, even though the engine technology was well-understood. It is estimated that an additional $500 million was spent on the aircraft nuclear propulsion program, because the X-211 turbine engine was built and tested despite the substantial technical and cost risks for the reactor. The program was eventually canceled because of the technical problems and costs associated with the nuclear reactor. This example highlights the need for sound judgment to select appropriate prototypes, at the subsystem level as well as at the system level.

C. TYPICAL APPLICATION

Prototyping may be accomplished at the system or subsystem level. It may be used during concept exploration to achieve a proof of concept, or during advanced development to achieve a proof of performance, cost, or operational suitability. An example at the system level of proof of concept would be a new vertical/short takeoff and landing (V/STOL) aircraft design approach such as the tilt-wing, fan-in-wing, or thrust-augmentation concepts. At the subsystem level, examples are the advanced turbine engine gas generator (ATEGG) and aircraft propulsion system integration (APSI) demonstrator programs for new aircraft turbine engine designs. Examples of proof of performance or cost might include the F100 engine competitive demonstration and the APG-63 radar competitive demonstration prior to the F-15 EMD start. Examples of proof of operational suitability include the YA-10, YF-16, and YAV-8B tactical aircraft, where the emphasis was on the ability of the aircraft to perform a useful operational mission. Operational prototypes can continue to be useful after EMD begins, because such prototypes can be used for certain testing before full-scale development test articles are available.

D. CASES EXAMINED

We cannot evaluate all the benefits of prototyping in a quantitative fashion. The information gained through prototyping is often not quantitatively measurable. In addition, one of the quantitative benefits, performance, is multi-dimensional and has different dimensions across equipment types. If a program proceeds well from a technical standpoint, then it is much less likely to encounter schedule and cost problems. Cost and schedule problems are measurable. By measuring planned vs. actual schedules and costs, we can compare program outcomes across equipment types.

The tactical aircraft cost-estimating relationships (CERs) are from the IDA study on tactical aircraft development costs [36], and the munitions CER is from Yates, Waller, and Vaughn [37]. There are some limitations in the data. We could not fully identify subsystem prototypes.

E. ANALYSIS

Correlation coefficients between cost and schedule outcomes and a prototyping dummy variable were estimated. They were always negative (lower cost growth in both phases and total, lower development schedule growth and lower development quantity growth for prototyped systems), but not statistically significant.

The outcomes for prototyped and non-prototyped programs are displayed for the total database and for types of equipment with more than five prototypes in Table V-1.

1. Development Cost Growth

This is one area in which aggregate outcomes differ depending on whether or not the observations are weighted. For the total database, non-prototyped systems have lower DCG when using current estimate weights, while prototyped systems are lower when using the unweighted data. Among tactical munitions, DCG was substantially lower.

2. Unplanned EMD Articles

Programs with prototyping needed only 5 percent more development items than planned, while non-prototyped programs needed 13 percent more. For munitions

Table V-1. Outcomes for Programs With and Without Prototyping by Equipment Type (Percent)

Outcome Measure	Aircraft		Tactical Munitions		All Programs	
	With Prototyping (N=11)	Without Prototyping (N=16)	With Prototyping (N=12)	Without Prototyping (N=23)	With Prototyping (N=39)	Without Prototyping (N=61)
DCGW	27	24	26	50	38	25
PCGW	27	38	56	149	36	64
TPCGW	25	32	48	120	35	51
DCGU	25	38	20	68	40	48
PCGU	21	30	51	108	43	65
TPCGU	19	31	44	93	40	56
DSG	9	17	49	47	30	37
DQG	13	9	-9	32	5	13

Notes: DCGW, PCGW, and TPCGW are weighted by the current estimate. DCGU, PCGU, and TPCGU are unweighted.

programs, prototyped programs built 10 percent fewer EMD articles than planned. On the basis of prototype testing, munitions program managers actually needed fewer EMD test articles than planned. This benefit is not seen, however, in the aircraft and the ships.

3. Production Cost Growth Lower

Production cost growth was less for the prototyped systems than for the non-prototyped systems overall. The difference was greatest for the tactical munitions, where weighted production cost for prototyped programs grew by 56 percent, while that for non-prototyped programs grew by 149 percent.

4. Levels of Development and Production Cost

To examine the effect of prototyping on the levels of development and production costs, we turned to a standard tool of cost analysis, cost-estimating relationships (CERs). CERs relate technical characteristics of a weapon system to its development or production cost. We examined the residuals of the CERs to determine whether there was any significant difference between prototyped and non-prototyped systems. If we found that prototyped systems had significantly higher residuals, this would indicate that a system with given technical characteristics would cost more if it were prototyped. Conversely, if we found that prototyped systems had significantly lower residuals, it would indicate that prototyped systems generally cost less than non-prototyped systems.

We were able to perform the tests for three equations: a tactical aircraft airframe full-scale development CER, a tactical aircraft production CER, and a tactical munitions full-scale development CER. For tactical aircraft airframes, there is no significant difference in either development or production costs that could be explained by prototyping. In the case of tactical munitions, there is no significant difference in development costs between prototyped and non-prototyped systems. (We were unable to locate a sufficiently aggregated CER to test munitions production costs.) Thus, the available evidence on total costs suggests that prototyped systems of equivalent technical capability do not cost significantly more or less than non-prototyped systems.

5. Schedule

Overall, prototyped programs took 2 years longer than non-prototyped programs from Milestone I to IOC (significance level = .06), but prototyping made no difference in the time from Milestone II to IOC. For the aircraft, there was no statistically significant difference in either interval. Prototyped aircraft took slightly less than 9 months longer from Milestone I to IOC (117 vs. 108 months), but Milestone II to IOC times were virtually identical (69.6 vs. 70.4 months). The prototyped munitions took over 2 years longer than non-prototyped munitions (135 vs. 104 months), but the difference was not statistically significant. (Moreover, the more complicated munitions were prototyped. When we control for this relationship, the time difference decreases to 1 year.) The length from Milestone II to IOC was actually 5 months shorter for the prototyped munitions, but again was not statistically significant.

We also examined more detailed evidence on schedule for a set of nine tactical aircraft programs. We examined these programs as to the impact that prototyping had on schedule length, including the advanced development period, FSD start to first flight period, and EMD start to 24th unit delivery period. The F-16, A-10, and AV-8B are the prototype programs, and the F-4, F-14, F-15, F/A-18, F-111, and S-3 are the non-prototype programs. (We considered the F/A-18 a non-prototype program because of the extensive changes in the Air Force prototype design that resulted in the Navy EMD design.)

The results of the analyses for the three time periods are presented in Table V-2. The first equation indicates that prototyping increases time in the pre-FSD period by 19.33 months, more than doubling it. However, time to first flight (in the second equation) is reduced by 2.7 months. Overall FSD time (third equation) is around 11 percent less with prototyping.[2]

Evidence shows that the prototyping experience reduces time in FSD, because the prototype can be used early in FSD, prior to the availability of development test articles, helping to gain information early in the program. Thus, the cost and time penalties associated with prototyping are not necessarily as large as might be assumed by simply adding a prototype program on top of an EMD program. Gaining information and choosing attractive options while precluding unattractive options can particularly benefit complex high-cost programs. The evidence from examination of tactical aircraft schedules bears this out with an 11-percent reduction of FSD time (resulting in an overall schedule increase of 15 percent from start of advanced development to delivery of the 24th aircraft).

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2 The overall FSD equation was run using a multiplicative specification:

$$T24 = b1 * A^{b2} * e^{(COMPANY*b3)} * e^{(PROTO*b4)}.$$

In order to interpret the results more easily, the parameters associated with the two dummy variables (b3 and b4) were converted from exponents to multipliers. Thus, prototyping is associated with an overall FSD time that is 89 percent of the FSD time without prototyping.

Table V-2. Effect of Prototyping on Development Schedule Periods

Pre-FSD Period

$$PFSD = 13.0 + 19.33\ (PROTO)$$
$$\quad (.0002)\ (.0005)$$

$N = 9$; $R^2 = .84$; Adjusted $R^2 = .81$; SEE $= 4.55$

Time to First Flight Period

$$TFF = 25.1 + 6.9\ (COMPANY) - 2.7\ (PROTO) + 2.9\ (TEAM)$$
$$(.0001)\ (.002)\qquad (.065)\qquad (.060)$$

$N = 9$; $R^2 = .93$; Adjusted $R^2 = .89$; SEE $= 1.6$

Overall FSD Period

$$T24 = 22.1\ (A)^{-.141} \times 1.15\ (COMPANY) \times .89\ (PROTO)$$
$$(.0011)\quad (.054)\ (.035)\qquad (.075)$$

$N = 8$; $R^2 = .95$; Adjusted $R^2 = .91$; SEE $= .05$

Source: Reference [34].

Notes: Significance levels are in parentheses. PROTO = dummy variable to indicate whether or not there was prototyping; COMPANY = dummy variable to indicate McDonnell Douglas as prime contractor; and TEAM = dummy variable to indicate major subcontractor/contractor teaming arrangements.

Thus, prototyping may take some additional time. This time, however, must be weighed against the gains in cost and technical predictability. In addition, the extra time occurs at a point in the program when spending rates are low [35].

6. Diverse Strategies Among Weapon Types

The two equipment groups in our study that had the most prototyping were aircraft and tactical munitions. We observed very different strategies regarding the prototyping of these two groups. Among the aircraft, the systems pushing the state of the art the least (such as the F-5E and the F-16) were prototyped, while others that were more technically difficult (like the F-14) were not. In the munitions, the opposite occurred. Systems with a high level of technical "reach" like Hellfire, HARM, and Harpoon were prototyped.

The strategy used for munitions was the more successful of the two. Munitions are often high-risk programs in general. They are less glamorous than aircraft and therefore seem to get less management attention. Perhaps the building and testing of a prototype serves to focus attention on the program. In any event, the munitions strategy was strongly successful. We would expect the munitions with high technical reach to have higher cost growth than those with low reach. In fact, those complicated munitions that were prototyped did *better* than the simple ones that were not prototyped. In the aircraft, by contrast, the prototyping strategy did not seem to be as successful.

F. FINDINGS AND RECOMMENDATIONS

Prototyping helps developers and users to understand the technical risks and uncertainty of the requirements. The quantitative evidence about the benefits of prototyping is generally positive although not statistically significant. The lower development cost growth effect is particularly pronounced for technically challenging programs. Development quantity growth, the need to build unplanned EMD articles, is less for tactical munitions programs. The benefits of prototyping also carry over into production. Production cost growth is generally less for prototyped systems.

These benefits come with some increase in development time. However, this additional time is not necessarily very long (and not statistically significant) for aircraft, and, for the tactical munitions, it may be more related to technical challenge than to prototyping. Prototyping is a leveraged investment. The government is buying information relatively cheaply, early in the program, rather than discovering problems in EMD or production, when costs (and rates of expenditure) are higher. Contrary to the conventional wisdom, our evidence suggests that prototyped programs do not cost any more than non-prototyped programs.

Prior studies of prototyping have been qualitative and have emphasized the uniqueness of each acquisition. Despite this uniqueness, policymakers should use consistent, clear lessons from past programs to set strategy for new programs. The evidence indicates that prototyping is a successful initiative when used appropriately.

Prototyping enhances the credibility of major programs, particularly given the tendency to underestimate technical risk. For all-new systems, the concept demonstration phase is particularly important. Operational suitability prototyping is particularly important in times of budget crunch, since we are particularly eager to know whether a system will work significantly better than what we already have.

Prototyping should be pursued vigorously where significant information is to be gained and the prototype represents only a small percentage of acquisition costs. Given the variability of these findings, guidelines should be adopted that provide bounds to costs for the benefits to be expected from a particular application of prototyping.

The type and extent of prototyping to be done also depends on the nature and extent of risk in the program. If the risk is largely technical, then concept and design prototyping are the most important. If the risk is that requirements are uncertain, then proving the technology is operationally suitable is most important. If there are concerns about production costs and producibility, it may be necessary to add a test of operational suitability with production article(s).

As rules of thumb for when prototyping makes sense relative to its likely payoff, we suggest that the prototype cost should be less than 25 percent of the EMD cost estimate, 10 percent of the acquisition cost estimate (EMD and procurement), or 5 percent of the life-cycle cost estimate, whichever is highest.

These rules of thumb can be adapted for technical risk and schedule criticality. If technical risk is high, then the cost estimates upon which these rules of thumb are based have considerable risk attached to them. For example, if technical risk is low, schedule is critical, and a prototype would cost 20 percent of EMD cost, then it would not make sense to undertake one. On the other hand, if technical risk is known to be very high, schedule is not critical, and a prototype would cost 30 percent of the EMD cost estimate, then prototyping makes sense.

Our quantitative analysis was not extensive enough to support development of a cost/benefit model for prototyping. Nevertheless, we have taken some important first steps toward such a model. A key element of such a model is a better measure of technical risk early in the acquisition process.

It would be useful for the government to capture the costs of prototypes to refine EMD and procurement cost estimates. The literature on this subject is surprisingly sparse.

It would also be useful to study the impact of prototyping in combination with other initiatives such as design-to-cost and contract incentives. In addition, the impact of a generalized strategy of prototyping across programs should be assessed. This should include its effect on competition and on the ability of industry to develop and produce new, technologically sophisticated weapon systems.

VI. CONTRACT INCENTIVES

A. BACKGROUND

Incentive contracting has a long history in acquisition. The early 1960s was an "incentive era" in which the government attempted to reduce costs through increased use of firm-fixed-price and incentive-type contracts [38]. Two general types of incentive contracts are in use today—cost plus (or fixed-price) incentive fee and cost plus (or fixed-price) award fee.

In fixed-price-incentive contracts, the contract has a target and a ceiling price. If the contractor meets the target price, it receives the full incentive fee. If it goes over the target price, costs are split with the government according to a sharing formula (50/50, 60/40, etc.) up to the ceiling price. Costs above the ceiling price are covered by the contractor. Incentive contracts can also be written to include incentives for system performance or delivery schedule. However, the most prevalent reason for incentive contracts is to share cost risks with the contractor. The government wants the contractor to produce efficiently and at the lowest cost.

Fixed-price award fee contracts have widely differing structures. Under these contracts, the fee is awarded based upon performance of goals set out in the contract. Award fee contracts are more flexible than incentive fee contracts. They can incorporate a variety of goals, including non-cost goals such as delivery dates or reliability and maintainability goals. Weights may be given to individual goals. A review board may be appointed to determine how much of the fee is to be awarded.

The General Accounting Office (GAO) reviewed 62 fixed-price incentive contracts from 1977-84 to determine how the final price of each compared with the contract's established target and ceiling prices [39]. Fifty-six of these contracts were for over $1 million and 22 were for over $10 million each. GAO analysts expected to find a clustering of final prices very close to the target price and an increasing tendency for final prices to be lower than the target price (or for lower overruns) as contractor sharing ratios increased. They found that the final prices on 58 percent of the contracts were within 5 percent of the target, and 92 percent were within 10 percent of the target. However, GAO's findings and other research findings cited in the report were that final contract costs and price seem unrelated to the sharing ratio.

B. BENEFITS AND WEAKNESSES

Benefits of contract incentives to the government include:

- Cost savings compared with what costs would be in fixed-fee contracts
- The degree to which the contractors behave in the way the government wants.

Advocates of incentive contracts would say that they are a good substitute for competition, which is very difficult to establish in major weapons systems because of the small size of the industry. Incentive contracts are an attempt to create market-like signals in an industry in which competition is difficult. The rationale is that the use of incentive fees and award fees is a low-cost, high-leverage proposition. Unlike some of the other initiatives we have examined, such as prototyping and competition, incentive contracting does not involve substantial up-front costs.

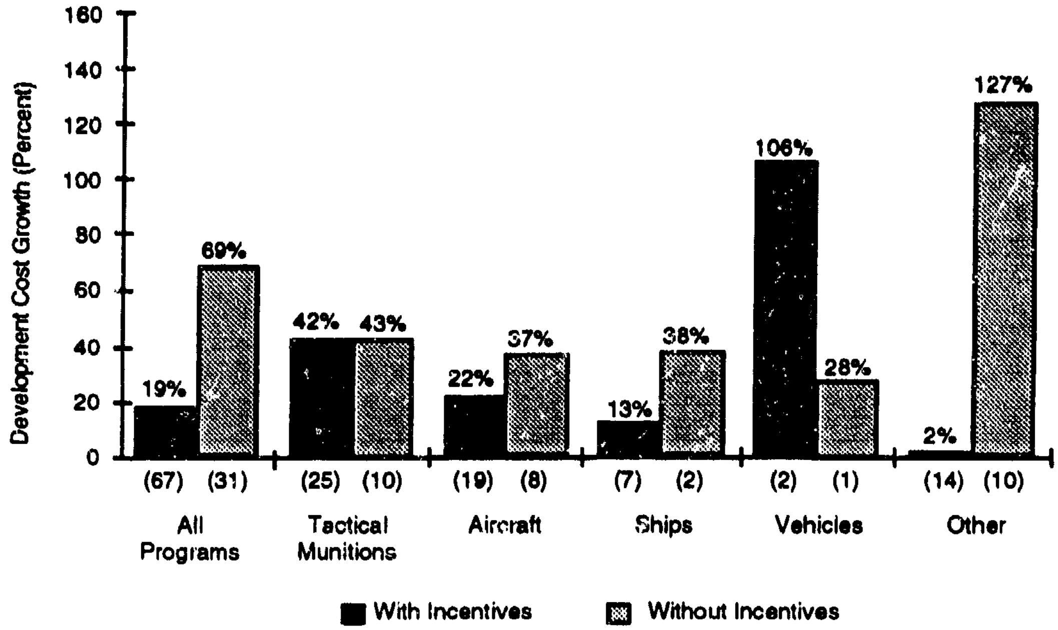
Weaknesses of incentive contracts are the additional costs to the government, including the following:

- The extra costs of incentive and award fees over and above those that would be given on cost-plus contracts and
- The extra cost of administering incentive contracts, as opposed to cost-plus contracts. (Award fee contracts may have higher administrative costs than incentive fee contracts, because of the necessity of measuring and monitoring contractor performance.)

Another possible pitfall is that cross-program effects may dominate and increase costs. For example, suppose that a contractor is working on two programs simultaneously in one plant. Program A is sole source, while Program B is competitive. Even if the contract for Program A has an incentive clause, it may make sense for the contractor to define costs in a way that increases the cost of Program A and keeps the cost of Program B low, in order to keep the competitive Program B.

C. ANALYSIS

Our database had 67 programs with incentives of any type in EMD and 56 with incentives in production. In most cases, the information we had was an indication of whether or not incentives were used rather than information on types, sharing ratios, and provisions of individual contracts. Figures VI-1 and VI-2 show outcomes for programs with development contract incentives and production contract incentives, respectively.



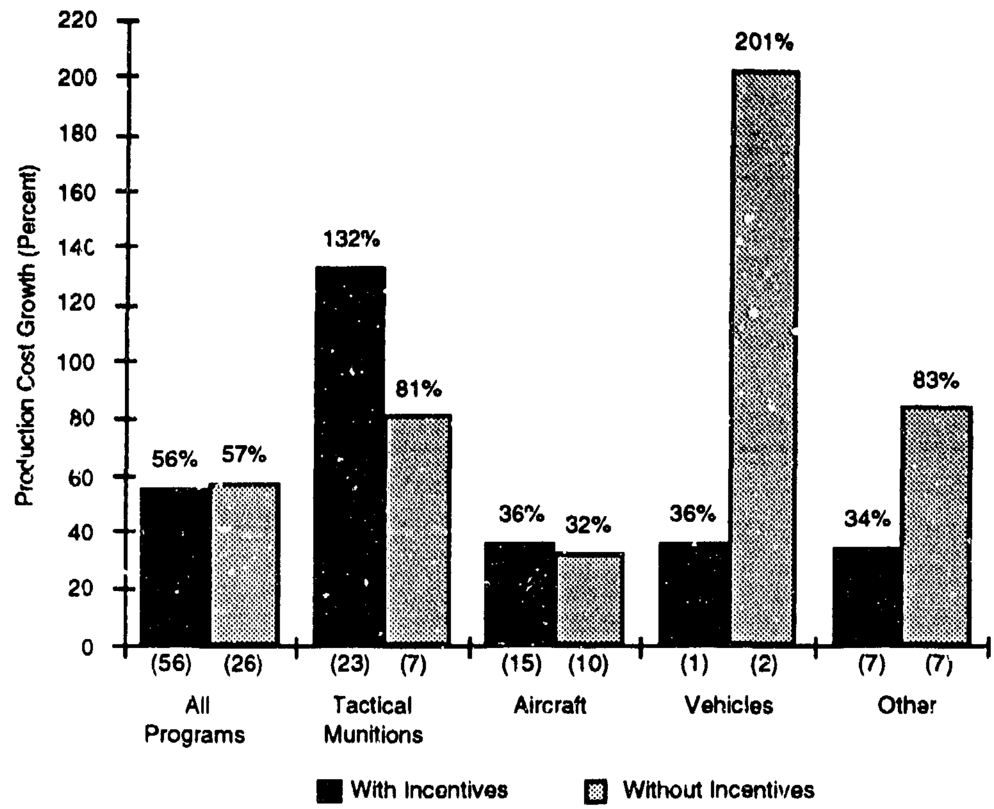
Notes: Numbers in parentheses are numbers of programs. Difference was statistically significant for the following: all programs, ships, and other.

Figure VI-1. Development Cost Growth for Programs With and Without Incentives in FSD

Figure VI-1 indicates that development cost growth is lower in programs with incentive contracts. This is true for all of the equipment groups we examined except for the vehicle programs, which are few and have displayed anomalous results in several areas. Some of these differences were statistically significant: ships (.02), other (.01), and overall (.09).

In production, the results are mixed. Contract incentives in production seem to have the biggest cost growth reduction effect in the "other" category and in the vehicles. For all of the other equipment groups, cost growth is higher for programs with contract incentives. None of the differences were statistically significant.

We make two observations about these results. First, our measurement was very simple. We included as incentive contracts any type of incentive contract awarded to a prime contractor at any time. In EMD, there are relatively few contracts, so this measure is fairly pure. In production, however, it is typical to produce the first few lots under cost-plus contracts, then to move to fixed-price incentive contracts when production procedures are well-established. Thus, 57 of our programs have incentives in production, while only 25 do not. More work is needed on measurement issues. Second, the results are intuitively appealing. Incentive contracts appear to have positive effects in development. In production, costs tend to be influenced by many factors other than contract type, such as stretch. Programs without production incentives tended to be stretched more than programs with incentives. However, the production result is also consistent with the possibility of perverse cross-program effects. Overall, these results indicate the potential for digging deeper.



Notes: Numbers in parentheses are numbers of programs. All ships had production incentive contracts, and their mean cost growth was 11 percent.

Figure VI-2. Production Cost Growth for Programs With and Without Incentives in Production

IDA case studies, program office visits, and industry surveys from prior work [1] indicated that incentives were successful. Both government and industry believed incentive contracts to be effective, although we did not independently evaluate savings estimates. In general, government representatives believed that they received what they wanted in cases of award fee. Industry representatives pointed out that incentive and award fees, which might seem small as a percentage of the total contract, amount to a large percentage of total allowable profit. Managers' bonuses might be tied to their performance in obtaining full incentive or award fees.

D. FINDINGS AND RECOMMENDATIONS

IDA found that development cost growth was lower for programs with incentive contracts than for programs without them. In production, results were mixed.

Contract incentives are a readily available, cheap way of potentially reducing costs, without imposing new regulatory burdens and without the need for new legislative authority.

Our findings on incentive contracts need to be considered in the context of two initiatives with similar cost-reducing objectives—competition and fixed-price development. The acquisition environment of the 1990s may not be all that hospitable to competition, because the number of potential competitors will be declining. In addition, because of the decline in the number of programs going into production, the old strategy of underestimating development and "getting rich" in production will be less available. In this environment, are incentive contracts a good substitute for other, less practical initiatives? With respect to competition, incentive contracts appear to be administratively simpler, although the potential savings may be lower. With respect to fixed-price development, incentive contracts appear to be more successful.

In the new environment, it seems worthwhile to have incentives available as an option. IDA macro and micro analyses pointed to the same conclusion: contract incentives work, at least in development. Moreover, contract incentives are fairly simple and inexpensive to implement. However, much more information is needed on how to design and time incentives so that they work best.

Based on our analysis, we recommend:

- Wherever possible, incentive contracts be used in development, and
- Measures of contract incentives be refined to include exact contract type and, for production, the lot numbers to which incentive contracts were applied.

VII. MULTI-YEAR PROCUREMENT

Multi-year procurement (MYP) describes the acquisition situation where DoD contracts for more than the current year's requirement. DoD's planned requirements, for up to a five-year period, are acquired without having total funds available at the time of contract award. Thus, an MYP contract is an alternative to a series of annual contracts in which the end items are procured one year at a time. Through economic quantity buys, MYP is expected to reduce the cost of procuring a weapon system.

A. BACKGROUND

The U.S. Army began testing the concept of MYP on small automotive motors in the early 1960s. DoD actively used MYP for weapon systems acquisition throughout the 1960s. During this period, weapon programs were typically funded with no-year (no two- or three-year obligation requirement) funds, and no special authorization was required to award contracts on a multi-year basis. DoD claimed cost savings and a high degree of program stability [40].

In 1972, the Navy canceled a pair of shipbuilding contracts incurring cancellation charges of $388 million. Although the problems with these particular contracts were not necessarily related to the fact that they were multi-year, Congress nonetheless was not pleased with such a large unfunded liability. To prevent a recurrence of these unexpected cancellation payments on multi-year contracts, Congress established a maximum cancellation ceiling of $5 million in the FY 1973 Defense Authorization Act. Contractors refused to accept multi-year contracts for major systems acquisitions with only $5 million cancellation ceiling. If a major program were canceled after the first year, the contractor would face significant unrecovered costs. For the remainder of the 1970s, the effect of the limit on cancellation ceilings was to virtually eliminate the use of MYP on major systems acquisition [40].

A Defense Science Board (DSB) study rekindled interest in MYP by estimating the DoD could save 10 to 15 percent of program costs by using MYP on major programs [14]. DoD endorsed the DSB position, and Deputy Secretary of Defense Frank Carlucci adopted expanded use of multi-year procurement as one of the "Carlucci initiatives."

Congress passed legislation in the FY 1982 Authorization Bill, Public Law 97-86, set out guidelines for MYP. Public Law 97-86 authorized:

- Cancellation ceilings of $100 million without notifying Congress. Thirty days notice to Congress was required for contracts with ceilings in excess of $100 million. Ceilings could either be funded, or left unfunded and carried as a contingent liability.
- Use of MYP with annual funds for supplies and services.
- Broadened coverage of the cancellation ceiling to include recurring costs (costs of out-year components, parts, and work in process), as well as previously allowed non-recurring costs and economic lot buys.
- Advanced buys, both in the case of long-lead-time items and economic order quantities, for more than one year beyond the current year's requirements.
- MYP contracts to cover up to a five-year period.

In Public Law 97-86, criteria were established that multi-year candidates must meet with congressional approval prior to authorization of funding. In order for MYP to be of benefit to the government, the estimated cost savings have to be significant because multi-year contracting can reduce future budget flexibility. Whether savings are enough to offset the risks imposed by reduced budget flexibility is judged by Congress. In the past, Congress has asked the General Accounting Office to make this assessment [41 through 43]. To do this, program risk in the following areas is assessed:

- Confidence in the cost estimate,
- Requirement stability,
- Funding stability, and
- Configuration or design stability.

Confidence in the cost estimate requires that the contract cost estimates and the anticipated cost savings be realistic. Cost savings are figured as the difference between cost estimates, proposals, or negotiated prices for the multi-year contract and the cost of procuring the same quantities in the same time periods with successive annual contracts. The services generally use proposals or negotiated contracts from the applicable contractor on both an annual and multi-year basis, and then compare and analyze those proposals to estimate savings from the MYP approach.

A stable requirement means the total quantity and procurement rate will not vary substantially (principally avoiding downward adjustments) over the term of the multi-year contract. Decreases in the procurement quantities can cause termination of the multi-year contract and create unit cost increases, which could reduce savings.

Both DoD and the Congress must be committed to ensuring that sufficient funds are provided to complete the multi-year contract at planned production rates. A turbulent funding history for a weapon system may suggest an unstable requirement, a relatively low funding priority, or wavering support; this may make the system inappropriate for multi-year contracting. Disagreements among the military services, OSD, and the Congress concerning the appropriate production rate and required funding for a system are often signals that funding is not stable.

Test and evaluation should be complete and demonstrate that the system, and therefore the design, is operationally effective. The Senate Committee on Appropriations, has always recommended that the multi-year approach be reserved for established production operations and state-of-the-art technology. Moreover, a program should be judged mature and stable only after research and development and one or two production runs have been completed successfully.

After passage of Public Law 97-86, the DoD immediately claimed savings of $325 million by using MYP for FY 1982 weapon system programs. In 1983, the Grace Commission advocated greater use of MYP [10] and stated that DoD might save as much as $3 billion over the next several years with more aggressive use of MYP [40 and 44]. However, in 1983 Congress placed limits on the use of MYP. Advance congressional notification of all MYP programs with cancellation ceilings over $20 million, rather than over $100 million, was required. Congressional notification of all economic order quantity purchases was required. Congress also imposed a requirement that all four Defense Budget committees be notified of programs selected as MYP candidates.

To provide greater assurance of the validity of estimated savings, the Congress has mandated a two-step multi-year approval process: Proposed multi-year contract costs are provided both with the budget submission and again just before contract award. Defense Appropriation Acts since FY 1984 have included language that reserves final multi-year approval until negotiated contract prices are submitted to the House and Senate Armed Services and Appropriations Committees at least 30 days before the contract award. This allows the committees to compare the estimates presented in the justification packages with the actual proposed contract amounts.

In 1990, GAO examined 6 programs that had been approved for multi-year procurement by OSD and the Congress, to determine the extent to which the MYP criteria had actually been satisfied [45]. All six programs failed one or more of the criteria.

B. BENEFITS AND WEAKNESSES

In its fiscal years 1982 through 1989 budget requests, OSD proposed at least 60 candidates to Congress for approval of multi-year procurement authority. OSD estimated a total potential savings for these programs of approximately $13.4 billion then-year dollars. Total procurement value of the multi-year candidates was estimated as $78.8 billion with multi-year contracting. The information was accumulated from the FY 1982 through FY 1989 OSD "Justification of Estimates for Multi-Year Procurement."

Typically, the majority of savings in a multi-year arrangement comes from the ability to procure vendor items more economically on a multi-year basis than on an annual basis. Manufacturing savings, slightly more than a third of the planned total, are achieved by increased prime-contractor manufacturing efficiencies made possible by stable production rates and the increased length of production.

Multi-year justification packages submitted to Congress often include estimates of industrial base enhancements that would result by applying the multi-year approach to any candidate weapon system. Examples of anticipated enhancements cited by the services include:

- Enhanced investment in infrastructure at the prime contractor and vendor levels,
- Enhanced training programs,
- Improved vendor skill levels, and
- Improved competition at vendor levels.

These enhancements then translate into increased production capacities and increased effectiveness.

The stability in contractor and subcontractor operation associated with multi-year contracts can create a level of business certainty more conducive to enhancing the industrial base than annual procurement. Nevertheless, it is difficult, if not impossible, to identify the industrial base enhancements that have occurred as a result of a multi-year contract that would not have occurred under annual contracts. No attempt to quantify a value for industrial base enhancements was applied during this analysis.

In spite of the potential benefits, several weaknesses of MYP must be considered. They are:

- Multi-year contracting can reduce future budget flexibility for DoD and the Congress. This is especially true in times of budget uncertainty and declining budgets. If budget conditions are expected to be unpredictable (or general funding to be unstable) during the timeframe of a proposed multi-year contract, and if changes are forced on the MYP program, OSD has two options: (1) renegotiate the MYP contract or (2) cancel the contract. In either case, the result is likely to be more costly than a series of annual contracts over the same time period would be.
- Multi-year contracting requires a substantial amount of up-front funding. The government will incur higher borrowing costs associated with accelerated expenditures under multi-year contracting. Cost savings must offset these additional government borrowing costs.
- Multi-year procurement contracts often specify a contractor cancellation fee. In order for MYP to work, the contractor must feel protected enough to procure from vendors at economic rates. The cancellation fees ensure that if the contract is terminated, the contractor and vendors to the prime contractor will not go entirely uncompensated for procurement of parts or materials greater than would have been procured in an annual contracting environment.
- MYP can result in loss of design flexibility. Unanticipated changes in the threat and incorporation of rapid changes in technology cannot be easily addressed in the multi-year environment. Renegotiation of the multi-year contract is generally required Even so, changes may be more difficult to incorporate than under an annual contract. This is because the prime contractor may produce heavily in the early years of the multi-year contract and may have tooled accordingly. At the very least, the prime contractor will have made commitments with vendors for materials, specified in the earlier design, that would make an immediate shift to the enhanced design costly.
- Use of MYP may also reduce the funding available for other acquisition programs. The full-funding requirements used under MYP can result in the crowding out of other programs. The services' flexibility in assigning priorities among various programs, and to reallocate funding among the programs, is reduced by MYP [46 and 47].

Primarily because of the funding commitments discussed in this section, neither the services nor the Congress have been willing to commit many programs to multi-year funding. Historically, fewer than half of the candidates proposed in any fiscal year are approved for multi-year funding.

C. ANALYSIS

We examined the programs in the IDA database that pursued a multi-year acquisition strategy to show whether or not MYP had indeed contributed to production and total program cost savings. We examined how MYP contributed to "cost savings" in the sense that these programs experienced significantly lower production and total program cost growth than other programs in the IDA data population. (MYP may contribute to the avoidance of cost growth experienced by programs pursuing other acquisition strategies.)

We assigned programs with production data available to one of four groups—mature MYP programs (those with three or more years of MYP experience), immature MYP programs (those with current MYP contracts, but with less than three years of experience), MYP candidates (those considered but not approved), and programs that were not official candidates for MYP. (Later versions of the Bradley FVS and MLRS had MYP contracts, but, since we examined the first version, we considered then to be non-MYP programs.)

The outcomes of the mature MYP programs are shown in Table VII-1. Table VII-2 compares outcomes among the four classes of programs.

Table VII-1. Outcomes for Mature MYP Programs (Percent)

Program	PCG	TPCG	PSG	PQG	Stretch
B-1B	-4	-1	-17	0	-17
F-16	21	21	351	361	-2
CH-47D	34	32	49	31	14
UH-60A/L	28	23	129	104	12
TOW	78	70	127	-41	285
DMSP	22	15	29	13	14
NAVSTAR GPS	24	11	71	93	-11
DSP	0	10	25	40	-11
DSCS III	70	74	-13	8	-19
Shillelagh	54	47	44	-11	62
Patriot	78	68	15	-54	161
MLRS	-12	-8	72	66	4
M198 Howitzer	29	31	-9	-11	2
SURTASS/T-AGOS	63	68	54	50	3
SSN-688	-1	-1	60	520	-74

Production outcome measures are considerably better for the mature MYP programs than for the non-MYP programs. Production cost growth is only 24 percent, vs. 69 percent for the non-MYP programs. MYP programs also tend to increase their planned production quantity and to be stretched considerably less. Production quantity growth is 78 percent for the mature MYP programs, vs. only 23 percent for the non-MYP programs. Mature MYP programs tend to be stretched less—27 percent vs. 81 percent.

Table VII-2. Outcomes for Programs With and Without MYP (Percent)

Outcome Measure	Mature MYP (N=15)	Immature MYP (N=5)	MYP Candidates (N=4)	Without MYP (N=58)
DCG	27	30	10	33
PCG	24	52	36	69
TPCG	23	45	29	55
PSG	65	67	113	49
PQG	78	14	54	23
Stretch	27	57	40	81

Note: Cost growth figures are weighted by the current estimate.

Critics of MYP argue that MYP uses a "cream-skimming" strategy—programs that receive authorization for MYP would have come out well anyway. In order to shed some light on this issue, we examined the outcomes of the MYP candidate programs. These programs were viewed by the DoD as meeting the criteria for MYP, but they were not approved by Congress. If the candidates had outcomes as favorable as the MYP programs, this would indicate that MYP has no independent effect.

The results of the MYP candidate programs are in-between—they exhibit better outcomes than the non-MYP programs, but not as good as the outcomes for the mature MYP programs. The difference in production cost growth, the key measure, is not statistically significant.

Surprisingly, the immature MYP programs exhibit higher production cost growth than the MYP candidates. Among these programs are Improved Hawk (207 percent production cost growth), AH-64A (85 percent), and IIR Maverick (55 percent).

By its very nature, multi-year contracting enhances program stability, which also contributes to lower cost growth. It is difficult to separate the effects of these two factors. However, the MYP candidate programs received roughly the same level of production stability (40 percent stretch vs. 27 percent for the mature MYP programs) and had higher cost growth.

D. FINDINGS AND RECOMMENDATIONS

The principal objective of multi-year contracting is to reduce procurement costs. OSD justifications indicate that the services expected to obtain savings of 10 to 20 percent when multi-year contracting is used. We were unable to examine cost savings rigorously. We were, however, able to observe considerably lower cost growth for multi-year programs as opposed to non-multi-year programs.

At least some of the favorable outcomes observed are probably due to the criteria that are applied to multi-year candidates—stable system requirement, system design, program funding, and because of this program and stability, confidence in the production cost estimate—rather than to the implementation of the multi-year contracting strategy.

The fifteen programs that have employed multi-year contracts for at least three years exhibit lower production and total program cost growth than do the general population of programs examined during this study. Programs that have MYP tend to be stretched out considerably less than non-MYP programs. In part, this is because the government wants to protect programs for which multi-year commitments have been made and to avoid paying cancellation fees. This added program stability certainly contributes to the low cost growth observed. However, we also observe that MYP candidate programs had about the same level of stability, but had 36 percent average production cost growth, vs. 24 percent for the mature MYP programs. This indicates that MYP is having some independent favorable effect.

We recommend that OSD continue support for multi-year procurement candidates. The office should continue use of the present guidelines that call for evaluation of stability of the requirement, the system design, the funding plan, and realism of the cost estimate. Our examples indicate that well-managed, stable programs can indeed benefit from MYP. However, applying MYP to all programs is impractical.

VIII. DESIGN-TO-COST

A. BACKGROUND

The design-to-cost (DTC) concept was instituted as one of several reforms to DoD procurement practices. Developed primarily by former Deputy Secretary of Defense David Packard and by former Director of Defense Research and Engineering (DDR&E) John Foster, the purpose of DTC was to develop a unit cost goal early in the design process and to design to that goal. DoD Directive 4245.3 of 6 April 1983 defines DTC as:

> ...an acquisition management technique to achieve defense system designs that meet stated cost requirements. Cost is addressed on a continuing basis as part of a system's development and production process. The technique embodies early establishment of realistic but rigorous cost goals, and thresholds and a determined effort to achieve them.

The DTC goal is initially expressed in terms of the average unit flyaway (or rollaway or sailaway) cost associated with an end item of military hardware. As the ability to translate operations and support cost elements into "design to" requirements improves, DTC goals and thresholds are related to total life-cycle cost (LCC).

On 13 July 1971, DTC became official policy in DoD Directive 5000.1. The directive provides that system development be "continuously evaluated against these (design-to) requirements with the same vigor as that applied to technical requirements." On 18 June 1973, Deputy Secretary of Defense Clements issued a memorandum entitled "Design to a Cost Objective on DSARC Programs," directing that a DTC goal be applied to all major DSARC programs. At this point the concept moved from being a goal (in DoD Directive 5000.1) to being a requirement for major programs in the acquisition process. In October 1973, two documents on methodology for DTC were released: (1) "Joint Design to Cost Guide," dated 3 October 1973 and (2) "Cost to Produce Handbook," dated 26 October 1973. Further refinement of the concept occurred in 1974.

In 1975, DoD Directive 5000.28 was issued imposing the concept of DTC on all acquisitions of major systems, requiring that cost be weighted equally with performance and schedule. According to the directive, DTC has a twofold objective:

- To establish cost as a design parameter equal in importance to technical requirements and schedules throughout the design, development, production, and operation of the system.

- To establish cost elements as management goals for acquisition managers and contractors to achieve the best balance among LCC, acceptable performance, and schedule [48].

In recent years, DTC has been used less frequently. While there is still a place in the SAR for the design-to-cost goal, it is often filled by an "N/A". Of the 64 programs with FSD start in the 1980s, only 27 are showing a DTC goal.

B. BENEFITS AND WEAKNESSES

The primary benefit of DTC is the requirement to estimate costs throughout the system's life cycle. Additional benefits are:

- DTC defines a measurable design parameter to be evaluated along with performance. A DTC parameter may be a goal or a threshold; values can be expressed in constant dollars, resources required, or other measurable factors that influence cost.
- DTC provides a basis for communication and coordination of effort between government and industry participants. The cost goals can serve as a "contract" between the program manager and the OSD for major programs or the services for smaller projects.
- DTC leads designers and production engineers to take a design/production team approach during the design process. For example, the A-10 effort by Fairchild incorporated the design/production team approach and produced its prototype in a configuration very close to the production model.
- DTC may provide easier maintainability through simplicity of design. Having to meet definitive cost goals may motivate the designer to look for the simpler, more maintainable design.
- DTC identifies specifications in minimum terms of performance, thereby providing the contractor with leverage to make cost-effective tradeoffs.
- DTC provides strong motivation to restrain cost growth.
- DTC can provide an early idea as to whether or not cost objectives will be met.

In spite of all the expected benefits, the DTC concept also has some weaknesses. These are explained below [49]:

- DTC may result in cost goals being established too early. DTC forces the program manager to commit to a DTC goal well before final agreement on configuration and operational requirements. Hence, the need to "sell" the program may drive DTC goals down to unrealistic levels. The key to the success of the DTC concept is the early determination of a specific cost goal; however, it may be extremely difficult to maintain a goal established so early in development. Tradeoffs are made. Test results may change the direction of the development. Reassessment of the threat may alter program direction. Environmental restrictions could alter the development of the system. Planned production rates may change in response to the results of initial tests. All of these items could drastically affect a goal based on a paper assessment. So one of the cornerstones of DTC itself represents a significant weakness of the concept.

- DTC may stifle innovation and restrict the use of new technology. A contractor with a specified cost goal tends to use what works, rather than trying a new approach that may reduce costs but involves risk.
- DTC could cause suboptimization. The short-term goal of meeting a specific cost ceiling may cause decisions that ignore long-term cost effects. When budget dollars and schedules are constrained, it is easy to ignore potential deficiencies because they will not be a problem for several budget periods, and then they will be someone else's problem.
- DTC results in performance buy-in. The contractor might promise superior performance at the DTC goal, but then fail to match claims with results after getting the contract. This problem can be partially eliminated through the use of contractor "flyoffs" or prototypes to determine how well promises match results.
- DTC imposes cost goals that are too detailed. If goals are established at levels too specific, the benefits of DTC in contractor flexibility and cost control might be adversely affected. The more that is specified, the less flexibility the contractor has in meeting cost objectives.
- DTC may increase development costs. The concept requires sufficient development time and money to be used successfully.
- DTC requires additional people, time, and effort to plan and execute the program.

DoD Directive 4245.3 requires the DTC goal to be established before Milestone I or at the earliest practical date thereafter, but in no case should the goal be established later than entry into EMD. In general, the DTC concept has not been properly applied. It has not been implemented early enough in the concept formulation phase. In most programs, the DTC goal was not followed through to completion. It either was dropped or faded away as the program progressed (Bradley FVS, M1 tank, F/A-18). The staff of the Directorate for Procurement Policy examined over 35 contracts that used the DTC concept and found that about 40 percent had the DTC requirements implemented *after* the contract was executed

[50]. For example, the DTC goal for the F/A-18 was implemented after the program entered the EMD phase.

C. ANALYSIS

We examined and compared development cost, schedule, production cost, and total program cost growth for DTC and non-DTC programs in three areas: across programs, by time period, and by service. To support our analysis we did case studies on three aircraft programs, the F/A-18, AH-64, and A-10, and looked at three additional programs, the MLRS, Bradley FVS, and the M1 tank. More information on the case studies are in the previous IDA report [1].

The only data available to IDA for examination of cost savings due to use of a DTC acquisition strategy were the program SARs and the IDA database (developed for macro-analysis). An important limitation of the database is the lack of information on operating and support costs. An important objective of DTC is to reduce life-cycle costs. We did not measure the impact of DTC an operating and support costs. Another potential impact of DTC that we could be missing is that of lower costs due to a lower cost goal.

A properly-implemented DTC program would begin during demonstration/validation, before the development estimate is made. Even if cost growth is the same, DTC may hold costs down.

Table VIII-1 shows the outcomes for DTC. Figure VIII-1 shows a comparison of cost growth for programs with and without DTC from our database.

Table VIII-1. Outcomes for Programs With and Without DTC (Percent)

Outcome Measure	With DTC	Without DTC
DCG	36 (39)	27 (59)
PCG	76 (34)	47 (47)
TPCG	64 (34)	38 (46)
DSG	35 (39)	32 (56)
DQG	6 (38)	13 (58)

Notes: Numbers in parentheses are numbers of programs. Cost growth figures are weighted by the current estimate.

As shown in Table VIII-1, total program cost growth in DTC programs is 27 percentage points greater than that of the non-DTC programs. Both development and production cost growth were greater in DTC programs, while there were no major differences in development schedule growth and development quantity growth. The overall statistics of the sample in our study do not exhibit cost savings being associated with the implementation of the DTC acquisition strategy. This indicates that DTC has not been effective as practiced.

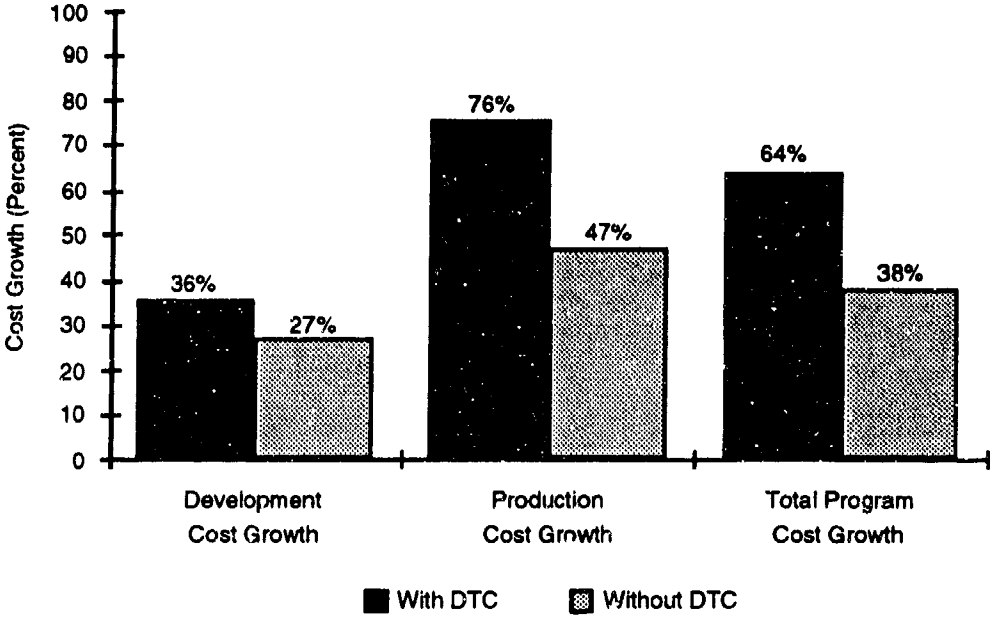
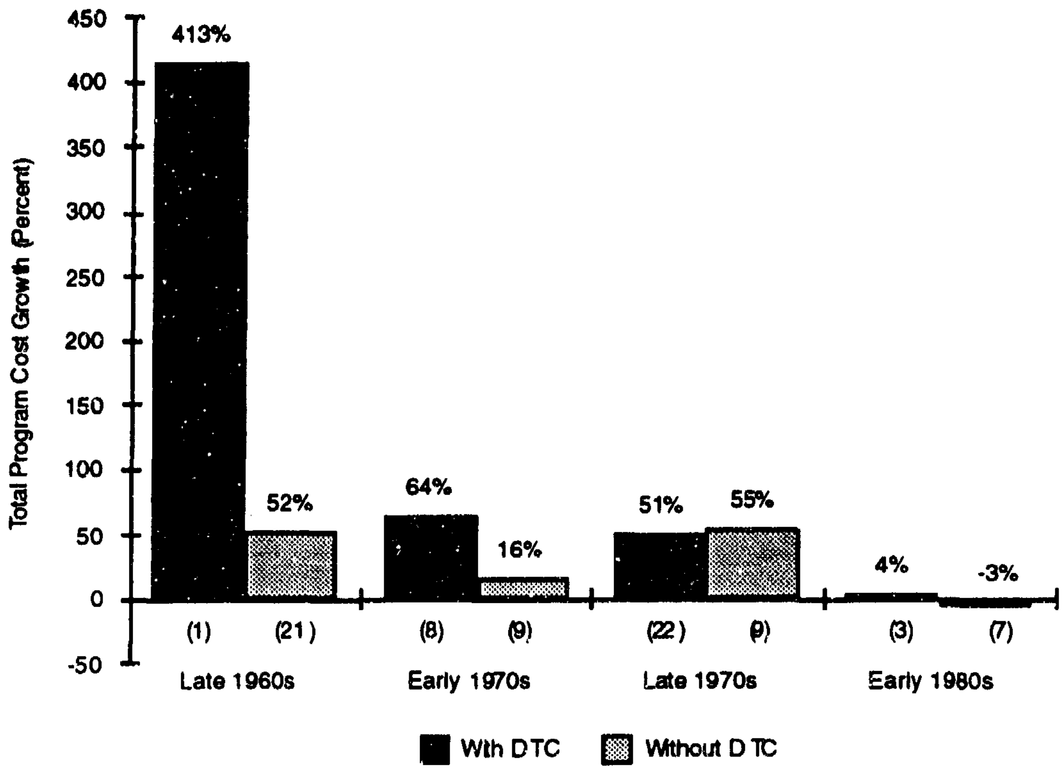


Figure VIII-1. Average Cost Growth for Programs With and Without DTC

However, the analysis of cost and schedule outcomes of programs with and without DTC by time period (Figure VIII-2) indicates that DTC programs starting in the late 1970s have slightly less cost growth than non-DTC programs. In this time period the cost growth of the DTC programs is only 51 percent and that of the non-DTC programs is 55 percent. This may indicate that, by the late 1970s, the DTC concept had enough time to become established and to be applied early enough in a program to be effective. Total program cost growth by FSD start year is presented in Figure VIII-3.

We also examined the outcomes of programs with and without the DTC acquisition strategy by service—Army, Navy, and Air Force. Our analysis shows that the Army's DTC programs have less cost growth than those without. On average, the Army's production and total program cost growth are higher than the Navy's and the Air Force's overall. For the Navy, programs with DTC have higher cost growth than the ones without. The Air Force program outcomes between DTC and non-DTC programs are about the same. The results of this analysis are shown in Figure VIII-4.



Note: Numbers in parentheses are numbers of programs.

Figure VIII-2. Total Program Cost Growth for Programs With and Without DTC By Time Period

To better evaluate the effectiveness of DTC acquisition strategy, we did short case studies for selected programs that used DTC to support the results of our macro-analysis. DTC programs produce mixed results in the program outcomes. Successful cases are the MLRS and A-10. Apparently the methods of implementing DTC make a significant difference in its success. Inappropriate implementation has substantially reduced the potential effectiveness of DTC [1].

Among our findings were:

- Most of the early systems we had information on had the DTC requirements forced upon them as a retrofit, after initial research and development (R&D) contracts were awarded. Because of this retrofitting, it is difficult to evaluate the effectiveness of DTC.
- System performance is still the first priority. Traditional emphasis on performance and schedule resulted in a relatively low priority being given to cost (e.g., F/A-18).

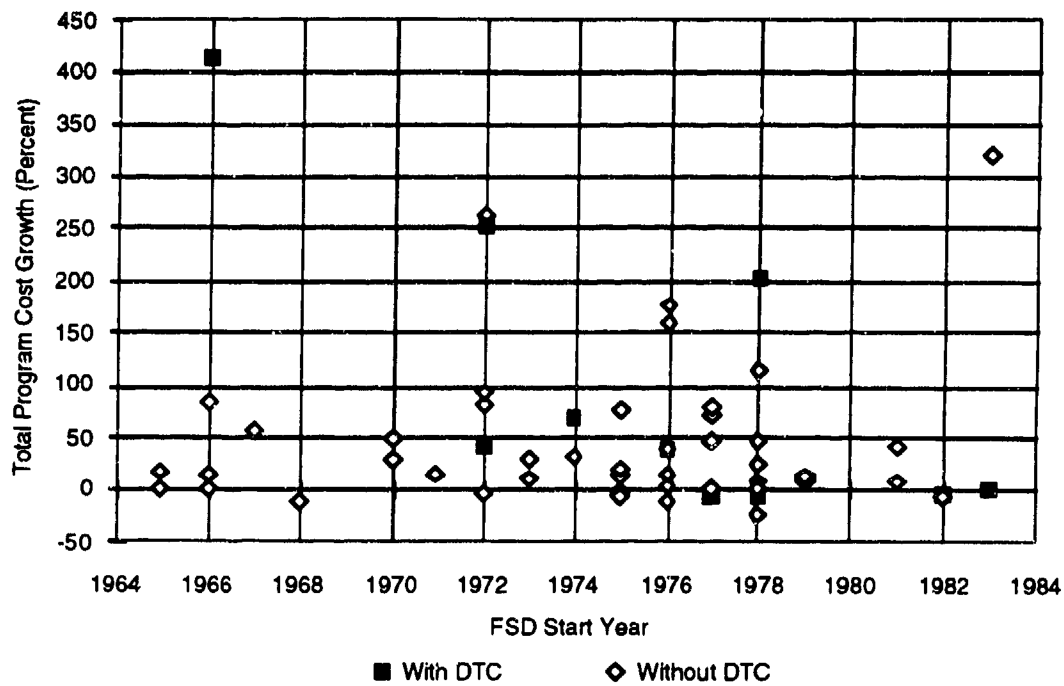
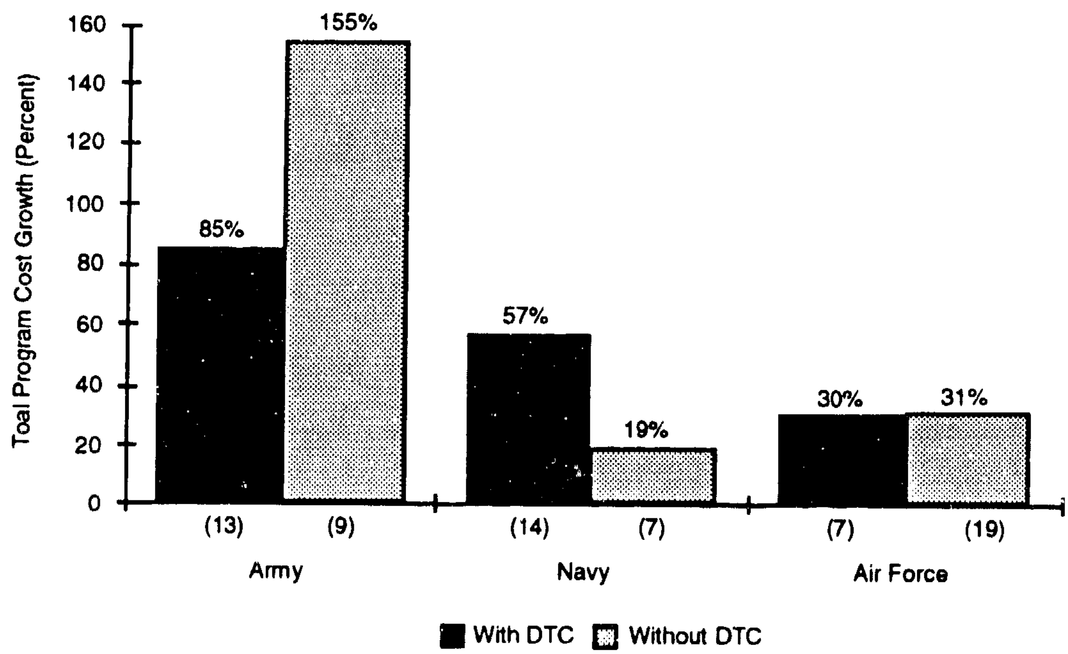


Figure VIII-3. Total Program Cost Growth for Programs With and Without DTC by FSD Start Year



Note: Numbers in parentheses are numbers of programs.

Figure VIII-4. Total Program Cost Growth for Programs With and Without DTC by Service

- DTC has been used mainly as a cost-monitoring device in FSD rather than as a tool for making tradeoffs earlier in the process (e.g., F/A-18).
- There has been an absence of continued technical evaluation of design/effectiveness/cost tradeoffs throughout the program acquisition phase (e.g., Bradley FVS).
- There has been no standardized method to implement DTC. Each DTC program uses its own management approach and definition. For example:
  - The A-10 program introduced a life-cycle-cost requirement of 10 years, but the emphasis was on meeting the stringent unit production cost goal in order to ensure program support.
  - The Utility Tactical Transport Aircraft System (UTTAS) program placed contractual DTC goals and incentives on average airframe production cost.
  - The contractor's cost model for the CH-47 modification program did not include the impact of tradeoffs in achieving DTC unit production goals on operation and support costs.
  - The F/A-18 program's DTC value was based on a cumulative average recurring cost for 800 aircraft.
  - The AH-64A program's DTC cost goal was based on the production cost for the A-10 airframe.

Generally, DTC targets (affordability limits) were not established during concept formulation, when the greatest flexibility existed to tradeoff performance for the dollars available (AMST, UTTAS, and CH-47 modification) [52].

DTC has the potential to produce significant cost reductions if problems of implementation could be resolved. The MLRS is a good example of a successful implementation of the DTC philosophy. The main factor that contributed to the success of the MLRS is the establishment of a realistic but still challenging goal. The key success of the implementation of the MLRS DTC goals was based on the following principles: stable specification and requirement documents, establishment of a design-to-unit-production-cost (DTUPC) goal for the total program and by fiscal year, compatibility of DTUPC quantities with procurement implementation plans, and costs and designs based on existing production technologies [53].

D. FINDINGS AND RECOMMENDATIONS

Based on our analyses of DTC, particularly the analysis of specific cases, we recommend the following:

- Establish DTC goal early. The goal must be established before the start of the validation phase, because it provides a baseline to work against in the tradeoff decisions, which occur during validation.
- Be flexible about the design. The number of specified performance parameters should be minimized in DTC. They should also be ranked according to priority, if possible.
- Use new technology to lower cost rather than to increase performance. This requires a change on the part of engineers who for years have been encouraged to rank performance over cost.
- Allocate the DTC goal down the work breakdown structure and track costs regularly for both prime contractor and subcontractor efforts. The DTC goal should be related to quantity from Unit 1 on up; setting a DTC goal for Unit 1 imposes strict discipline on the designer and permits an early indication of compliance.
- Use contractual incentives. Contractual innovations are needed to give the contractor an incentive to build a reliable, low-cost product. Reliability Improvement Warranties and award fees are two such devices.
- Allocate enough time and money to implement DTC. DTC should require that adequate time and sufficient funds are available during development to permit examination of tradeoffs and alternative design approaches. Constraining either may cause suboptimization.
- Establish realistic cost objectives. The goal should reflect the best estimate based on available data.

Most DTC programs in the sample applied DTC either as a retrofit or too late in the development phase (full-scale development) to be cost-effective. Other acquisition programs implemented DTC at the beginning, and as the programs progressed, dropped the strategy due to additional advanced technologies applied to the system's design because of requirements changes (e.g., Bradley, M1 tank). Our macro-analysis indicates that cost growth is greater for programs with DTC than for programs without, except in the late 1970s. This exception may be because the DTC concept had become well enough established by the late 1970s to be implemented earlier in the programs.

IX. DUAL-SOURCING

A. BACKGROUND

Defense acquisition has a long history of competition. The Armed Services Procurement Act of 1947 required that contracts for property or services be formally advertised. OMB Circular A-109 directs that competition be used throughout a program, particularly during design and development. Competition in design and development has the advantage of allowing the exploration of different alternatives. Competition often has been used in full-scale development. More recently, however, the government has emphasized dual-sourcing in production, the explicit goal being lower prices and, possibly, better performance.

In the 1980s, Congress prescribed production competition. In the Defense Appropriations Act of 1984, Congress required that any major acquisition program have either a certification that the system would be procured in insufficient quantities to warrant multiple sourcing or a plan for the development of two or more sources. The Competition in Contracting Act (CICA) of 1984 established requirements for maximizing competition. Competition was to be the norm; exceptions were to be justified. CICA required the appointment of competition advocates to review acquisition strategies. It both provided for specific procedures designed to guarantee that all sellers could bid for a proposed procurement and established protest procedures. Additional legislation—the Department of Defense Procurement Reform Act and the Small Business and Federal Procurement Competition Enhancement Act of 1984 and the Defense Procurement Improvement Act of 1985—also aimed to increase competition in defense contracting.

In addition, the Defense Department has encouraged competition. The Defense Acquisition Improvement Program (the Carlucci initiatives), instituted in 1981, includes an initiative to increase competition in the acquisition process. The Packard Commission recommended the use of commercial-style competition. It recommended development of a waiver before hardware could be uniquely developed for the military. In 1984, the Defense Systems Management College published a handbook for program managers on enhancing competition [54].

In 1989, the Naval Center for Cost Analysis examined twelve dual-sourced acquisition programs to determine the extent of any savings [55]. All twelve programs had net savings, ranging from 0.8 percent to 27.9 percent, with an average net savings across the twelve programs of 14.2 percent. Savings of less than 5 percent were estimated for the AIM-54C Phoenix missile and the F404 aircraft engine. For both of those programs, dual-sourcing was started late in the production span, and because of the technical complexity of both programs, there were very few firms that could qualify as second sources. Contractors on two other programs experienced severe financial problems, with mixed results on the program outcomes. Savings on the TAO-187 program were estimated to be a below-average 7.5 percent because of the bankruptcy and shutdown of Pennsylvania Shipbuilding, which led to additional costs for refurbishment and construction of partially completed vessels. In contrast, the LSD-41 program had the highest estimated net savings (27.9 percent) in spite of financial difficulties of the lead builder, Lockheed Shipbuilding and Construction; the last five ships were built by Avondale, with large savings after a winner-take-all competition. IDA has also reviewed additional studies on dual-source programs and recommended criteria for analysis [56].

The threat changes of the 1990s and the resulting reductions in funding available to the DoD imply major changes in the amount of dual-sourcing that is likely to occur. For many programs, there will be barely enough funding to sustain a single source. For new programs, there might be competitive prototyping, but sole-source production. In any event, stricter criteria for dual-source programs are likely.

In this study, we focused on competition as dual-sourcing in production for major weapon systems and subsystems. This type of competition typically requires that the government have a hand in developing an alternative source, just as it developed the first source. Other methods of enhancing competition in major weapons systems, including winner-take-all or vendor competition, are not discussed here.

B. BENEFITS AND WEAKNESSES

We can think of the types of items that the government buys as being along a continuum with respect to quantity and complexity. Small, uncomplicated items that the government buys a lot of over the years are easy to compete. In many cases, these items are standardized, and obtaining multiple sources is relatively easy. At the other end of the continuum, major weapon systems are developed on a customized basis and produced in relatively small numbers. A company that wants to produce Sidewinder missiles cannot merely do some quick tooling and start producing them—a detailed technical data package is needed.

Government funding of the second source is fairly common, as is the use of "educational buys" or "qualification buys" to get the second source started. Another common factor is the use of annual competitive bids between contractors. Typically, in major systems, these annual competitions are not winner-take-all, but the buy is split between the contractors. This practice requires the government to fine-tune its approach: the government must give the winner enough of a "reward" to encourage future low bids, but it must give the loser a large enough order to keep its production line going. Depending on how its bid is structured, a clever loser might end up with more profits than a winner.

In the short term, the expected benefits of dual-source competition in major systems include:

- Lower overall costs
- Increased contractor responsiveness to government needs
- Enhanced system quality and reliability, put in as an attractive feature for government purchasers. (A number of competitive programs we studied, including Tomahawk and the alternative fighter engine, were motivated more by quality considerations than by cost.)

Longer-term benefits could include:

- Enhanced industrial base for particular systems
- Increased capital investment by contractors.

In the short term, the weaknesses of competition include additional costs in areas not found in single-source production:

- Dual-sourcing typically requires an up-front investment for tooling, equipment, qualification, and administration to establish a second source.
- By splitting a buy between two contractors, the government may give up some economies of scale because the full benefits of learning and high-rate production are not realized. Large buys typically exhibit lower unit costs than small buys.
- If multiple configurations are required, support costs may increase.

Little attention has been paid to the possibility of long-term weaknesses of competition with respect to the relationships between industry and the Department of Defense. Are the benefits of dual-sourcing a one-time effect, or can they be sustained over time? Production competition in major systems must be viewed as an investment decision.

The potential reduction in procurement costs must be weighed against additional up-front costs and increased government administrative costs. This tradeoff is unique for each program.

The Defense Systems Management College program managers' handbook indicates a method for evaluating the impact of production-level competition on program costs. In evaluating potential or actual cases of competition, policymakers may find these guidelines useful [54, pp. 7-1, 7-2]:

(1) Estimate single source recurring production costs by fiscal year in constant dollars based upon progress curves and expressed as contractor price.

(2) Estimate competitive recurring production costs by fiscal year in constant dollars based upon progress curves. Reasonable assumptions must be made concerning shift and rotation and the second source progress curve.

(3) Calculate potential savings by subtracting (2) from (1) by fiscal year.

(4) Calculate net potential savings by subtracting annual incremental government costs, stated in constant dollars, from (3).

(5) Estimate nonrecurring start-up costs, stated in constant dollars, by fiscal year.

(6) Estimate incremental logistic support costs, stated in constant dollars, by fiscal year.

(7) Calculate a net present value of competitive versus sole source production costs by subtracting the discounted costs (5) and (6) from the discounted benefits (3).

(8) Compare discounted, constant, and then-year dollar estimates of single source and competitive production.

(9) Conduct detailed sensitivity analyses to investigate the effect of changes in key assumptions on the estimate of savings, and to develop a range of likely estimates.

C. ANALYSIS

Depending on the appropriateness and availability of data, we conducted an analysis of the program database described in Section III, including statistical analyses of cost growth estimates. Table IX-1 shows the outcomes for the dual-sourced programs.

We see considerable variability in the outcomes for dual-sourced programs. One unifying factor is low cost growth in ship programs (except the FFG-7). During the time that these ships were acquired, dual-sourcing in ship programs was virtually universal. It was also a time of considerable overcapacity in the shipbuilding industry. Dual sourcing interacted with industry conditions to create favorable outcomes.

Table IX-1. Outcomes for Dual-Sourced Programs (Percent)

Program	PCG	TPCG	PSG	PQG	Stretch
Hellfire	71	44	75	131	-24
Sparrow-F (AIM-7F)	58	75	22	66	-26
TOW	78	70	127	-41	285
Sidewinder-L (AIM-9L)	107	125	176	23	125
IIR Maverick	55	51	36	-37	114
Sparrow-M (AIM-7M)	28	26	61	41	14
Sidewinder-M (AIM-9M)	1	10	144	127	7
Phoenix-C (AIM-54C)	98	92	50	252	-57
Shillelagh	54	47	44	-11	61
MK 48 ADCAP	0	2	53	0	53
Stinger Basic/POST	84	87	-18	-60	104
Dragon	172	159	13	-73	313
Standard Missile 2	-9	-4	67	36	22
Tomahawk	57	45	29	235	-61
SURTASS/T-AGOS	63	68	54	50	3
CG-47	-6	-6	14	69	-33
DDG-51	-6	-1	111	322	-50
FFG-7	40	40	83	2	80
LHD-1	-6	-6	49	100	-26
LSD-41	-8	-8	0	-33	50
SSN-688	-1	-1	60	520	-74
T-AO-187	-8	-8	2	6	-3

Table IX-2 shows the results from the aggregate analysis. An analysis of averages from the full sample and from the group of tactical munitions and ships (where virtually all the dual-sourcing in our group of programs has occurred) is interesting. In production, where one would expect dual-sourcing to have the greatest impact, production outcomes were considerably more favorable for dual-sourced tactical munitions. Production cost growth for dual-sourced tactical munitions was only 54 percent, while it was 159 percent for non-dual-sourced tactical munitions.

We also see that production quantity growth is much higher in the dual-sourced programs, and program stretch is much lower. It appears that stable programs are chosen for dual-sourcing, or (more likely) that the government keeps competitive programs more stable, in order to protect its up-front investment.

Another equipment type with considerable dual-sourcing is ships. Production cost growth for dual-sourced ships was 4 percent on average, while it was 29 percent for the two non-dual-sourced ship programs. This adds to our favorable results for dual-sourcing.

Table IX-2. Outcomes for Programs With and Without Dual-Sourcing (Percent)

Outcome Measure	Ships		Tactical Munitions		All Programs	
	With Dual-Sourcing (N=8)	Without Dual-Sourcing (N=2)	With Dual-Sourcing (N=13)	Without Dual-Sourcing (N=17)	With Dual-Sourcing (N=22)	Without Dual-Sourcing (N=60)
PCG	8	37	54	159	26	65
TPCG	9	37	51	126	26	52
Stretch[a]	-7	147	77	158	40	77

Note: Cost growth figures are weighted by the current estimate.

[a] Condor (stretch = 5,600 percent) excluded from stretch calculation.

However, it is important not to make too much of the ship results, because the two non-dual-sourced programs were considerably older. During the 1970s and 1980s, ship dual-sourcing was the rule, and the shipbuilding industry had considerable overcapacity. Dual-sourcing probably contributed to the strongly favorable outcomes for ships relative to other equipment types.

D. FINDINGS AND RECOMMENDATIONS

The findings of our analyses of dual-sourced programs are summarized below:

- In missile programs, cost growth in dual-sourced programs was lower than in non-dual-sourced programs. While this difference was not statistically significant, it suggests that dual-sourcing may be beneficial. In ship programs, production cost outcomes were also favorable, but ship dual-sourcing was the rule. We do not have a good control group for the analysis, but dual-sourcing may have contributed to the strongly favorable outcomes for ships.
- It is easier to find savings in prices than in resource inputs. Several studies evaluating costs such as engineering hours and manufacturing inputs find similar direct resource usage in dual-source and sole-source programs. Thus, savings from dual-sourcing seem to come from either profits or the prices for inputs.
- Dual sourced programs tend to buy more quantity than planned over a longer period of time than planned. This tends to amortize development costs and second-source startup costs. It may be that the benefits seen from dual-sourcing are really benefits of program stability—this is a chicken-egg problem.
- Cross-program effects and industry strategies have been insufficiently analyzed. Even if we see savings from dual-sourcing, we also need to examine whether there are cost increases in sole-source programs produced in the same plant. Also, in some programs, such as Hellfire, we see a seesaw pattern of production, with the companies alternating winning the major share of the year's production. This pattern, if it is regular, allows contractors to plan stable production rates. One-shot gains may be possible as dual-sourcing represents a shock to the system—it is unclear whether or not such gains could be sustained were dual-sourcing to become a universal acquisition strategy.

(These findings pertain to major systems. For subsystems, the dual- or multiple-sourcing picture is quite different. Up-front investments are typically smaller than for full systems, the number of items being procured is often larger, and the items are frequently less complicated.)

Based on our findings, we can make the following recommendations regarding dual-source competition in major systems:

- Dual-source production should not be prescribed across the board for major systems. Competition can be of value in particular individual cases; however, it is very difficult to predict what those cases are. Based on our analysis, we can make the observation that conditions of industry overcapacity appear to be favorable to competition. The larger and more customized the system, and the lower the quantity, the harder it is for dual-sourcing to be viable because of the larger investment. Additional work needs to be done on criteria for competition.
- That cost savings from competition are uncertain should be recognized. It does not make sense to plan on large, immediate cost savings. Dual-sourcing requires some up-front investment, and payback occurs over a number of years.
- Specific guidelines should be established for dual-sourcing, similar to those for MYP. Competition is best applied under the following conditions:
  - a large number of systems are required,
  - a firm plan and stable funding are available,
  - break-even analysis suggests that costs can be recovered over a reasonable period,
  - technology transfer involved is relatively straightforward, and
  - adverse effects on other programs are negligible.
- Benefits other than reduced prices may exist and need to be considered. Among these are increased contractor responsiveness, increased system reliability, and preservation of the industrial base.
- Additional research should be done into the long-term effects of dual-sourcing. Such research should go beyond the individual program to consider overall contractor strategies that can affect the cost of other programs.

X. TOTAL PACKAGE PROCUREMENT AND FIXED-PRICE DEVELOPMENT

We analyzed total-package procurement and fixed-price development together because they have common implications—both shift risk from the government to the contractor. Total package procurement involves considerable risk for the contractor in both development and production, while fixed-price development involves risk in development, but not in production. Total-package procurement was begun in the 1960s, and fixed-price development was begun in the 1980s.

A. TOTAL PACKAGE PROCUREMENT

Total package procurement (TPP) was one of the first major initiatives developed by the DoD as an effort to restrain cost overruns in the weapon system acquisition process.

1. Background

In the mid-1960s, successful development contracts were generally followed by production contracts. Little or no likelihood existed that the developer would have to face competition. Thus, the contractors had incentives to "buy in"—to underestimate the cost of development programs in order to win the development contract and place themselves in a sole-source position for the much larger follow-on production contracts.

To attack this problem, Robert H. Charles, the Assistant Secretary of the Air Force at the time, designed the total package procurement concept. The objectives of this concept were to:

- Limit or eliminate buy-in considerations,
- Motivate contractors to design for economical production and enforce design discipline,
- Encourage subcontracts with, and obtain components from, the most efficient supply sources,

- Obtain long-term commitments leading to program stability and continuity, and
- Encourage contractor efficiency through competition and thereby reduce costs.

According to Charles, TPP would allow the government, like any buyer in the commercial world, "to make a choice between competing products on the basis, not of estimates, but of binding commitments concerning performance and price of operational equipment" [57].

TPP required contractors to bid on the development, production, and spare-part support work under one contract. Price and performance commitments were obtained during the contract definition phase. The purpose of the TPP contract, generally of a fixed-price incentive type, was to offer the government the opportunity to shift the major risk and major program management responsibility to contractors.

The results of the TPP initiative fell far short of the goals. Cost overruns continued, new defense systems failed to meet technical performance requirements, and schedules slipped on many programs. The reasons for the failure of the TPP concept are many. The onset of inflationary pressures in the economy during the Vietnam era—unrelated to a specific program—may have been partially responsible for the failure of the TPP concept. More importantly, TPP did not provide contractors with sufficient management flexibility to cope with problems as they became known. Contractors had to make substantial production commitments to meet delivery schedules before completion of design and verification by testing. Costly redesign and rework followed. Continued tradeoff analysis was stifled because of the rigidity of the contracts. Finally, the government typically did not enforce the total package procurement contract provisions if the contractor failed to achieve the program's goals. When problems occurred, the total package procurement contracts were converted to cost-reimbursement type contracts, and the contractors were required to take substantial losses on the program.

Although the Air Force's Maverick air-to-surface missile program successfully used the TPP concept, serious problems were encountered on many other total package procurement programs. Among those troubled programs were the Air Force Galaxy C-5A transport and Short-Range Attack Missile (SRAM); the Army Cheyenne AH-56A helicopter, which was canceled; and the Navy DD-963 destroyer and LHA-1 helicopter carrier. As a result of the problems encountered, DoD recognized the need to place stringent limitations on the application of TPP. By 1972, TPP was abolished by the Deputy Secretary of Defense.

2. Benefits and Weaknesses

The expected benefits of the TPP concept at the time of its introduction included:

- Better definition of design specifications. The TPP concept requires design tightening and configuration discipline on the part of the contractor. At the same time, it forces the government to define, early in the program, specifically what it wants.
- Less unrealistic "salesmanship" or "buy-in" bidding. TPP was designed to allow the Department of Defense to make a choice among competing contractors on the basis of binding commitments on the performance and price of the system.
- Better contractor commitment to design for economical production, reliability, and maintainability.
- More efficient selection of vendors. The contractor is motivated to obtain supplies from the most efficient sources.
- Less need for subsequent competitive reprocurement of components. This is due to increased competition at program initiation.
- More efficient contractors. The winning contractor is more efficient due to tougher competition at the beginning of the program.
- Better long-range planning required by both the government and the contractor.

Despite these promises, the TPP concept has some weaknesses. By attempting to fix a price on a paper concept for a future system, TPP fails to recognize risks involved in taking a design from paper to reality—potential for cost growth and technological risks. The costs identified by the contractor are only estimates and should be treated that way—provisions should be made for periodic updating. Also, the specific definitions of performance requirements, schedules, and production quantities restrict the contractor's ability to perform in the most cost-effective way when moving from design to actual hardware [58].

3. Analysis

Our analysis shows that the total cost growth in TPP programs is greater than the cost growth in non-TPP programs by 28 percentage points. The outcomes of TPP programs and the outcomes of the TPP versus non-TPP programs are presented in Table X-1 and Table X-2, respectively.

Cost growth in development and in production is substantially higher in total package programs. TPP programs also take longer than planned to reach IOC.

Table X-1. Outcomes for TPP Programs (Percent)

Systems	PCG	TPCG	PSG	PQG
C-5A	115	77	19	-34
SRAM	456	263	—	114
Maverick AGM-65A	-1	1	14	18
SURTASS T/AGOS	63	68	54	50
LHA	58	57	80	-44
DDG-963	23	23	78	3

Table X-2. Outcomes for Programs With and Without TPP (Percent)

Outcome Measure	With TPP (N=6)	Without TPP (N=76)
DCG	128	27
PCG	91	53
TPCG	72	44
DSG	54	34
PSG	49	57
PQG	18	35

Note: Cost growth figures are weighted by the current estimate.

While the goal of the TPP concept was desirable, the quantum leap in acquisition practice that implementation of the concept represented was a factor in its failure. TPP was an effort to change 30 years of acquisition in a single step. It depended on details and projections never before attempted for large programs. For example:

- It required detailed specification of performance requirements, schedules, and production quantities before a single piece of hardware had been built.
- It required that the contractors project requirements far into the future and provided no provision for revision.
- It attempted to set a firm price on the development and production of a complex system before any part of that system had been constructed.

The total package procurement concept shifts the major role of government personnel from the acquisition phase to the conceptual and definition phases. TPP shifts risk from the government to the contractor. To a certain extent, risk shifting may be a good idea. In private industry, companies that develop products bear all the risk. If those products are not acceptable to consumers, the firms are unable to sell them, and they lose money. Ultimately, these firms may fail. However, in major weapons systems, the product is developed on a customized basis for the government. If the government shifts too much risk onto the contractor and there is an overrun, the contractor's existence may be jeopardized. Then, the government has to decide whether to let the contractor go out of business or bail it out. In the cases of the C-5A, the DD-963, and the LHA-1, the government decided to bail out the contractors. Further, if contractors know that they are going to be bailed out, then major risk-shifting becomes less effective.

4. Findings and Recommendations

The total package procurement concept is a failure. It should not be implemented except in rare circumstances. TPP is most likely to have serious adverse effects on innovation and quality in systems developments where the requirement is uncertain, the need is extremely urgent, the technology that must be used is unproven, or the measures of systems effectiveness are diffuse and qualitative.

The total package procurement concept might have been successful if it had been implemented in a more orderly fashion, and if adequate time had been provided for both the government and the contractors to develop an understanding of the implications of the concept—the concept was introduced in mid-1964 and was first applied to a major system a few months later.

In order to implement TPP, the following conditions should exist:

- The system should be thoroughly and clearly defined in a contract definition phase.
- The program should be a low-risk development.
- The project should be short-term (5 years or less).
- An announcement should be made at the outset of the program that substantial changes are not permitted.

The Maverick AGM-65A proved that TPP can work under the right conditions.

Because most of the SAR programs are high-risk, it should generally not be applied. In particular, if the government and the contractor cannot agree on a stable system definition, the TPP initiative should not be applied.

B. FIXED-PRICE DEVELOPMENT

Fixed-price development (FPD) was instituted by the Navy in order to encourage an efficient development process without the major risk of total package procurement.

In a firm-fixed-price (FFP) contract, the contractor theoretically accepts all risks in exchange for the stated price. The government is required to make no price adjustment for the original work after the contract is awarded, regardless of the contractor's actual cost in meeting requirements. Exceptions occur in cases of government-approved contract changes made in response to changes in military requirements, technology, and funding. Changes may also be made in cases involving the "Truth in Pricing" law. This law makes provisions in cases where the contractor did not disclose information available at the time of the negotiation, causing inaccurate estimates. The firm-fixed-price contract can be defined as a contract that specifies a certain amount to be paid for the designated system, regardless of the contractor's cost experience.

1. Background

The practice of firm-fixed-price contracting by the DoD has gone through many changes over the past twenty years. In 1952 fixed-price contracts represented 82 percent of defense prime contract awards. By 1961 this had dropped to 58 percent. Defense Secretary Robert McNamara raised the percentage to 79 percent in 1966; by 1970 the fixed-price percentage had dropped to 74 percent.

Although the percentage of fixed-price contracts is partly a function of the type of work to be performed, it is heavily influenced by Pentagon policy. It is used to shift the burden of cost control from the DoD to the contractor. After 1969, the Laird-Packard influence led to a decline in fixed-price contracting and an increase in the use of cost-reimbursement contracts for research and development work. The Laird-Packard administration believed that large research and development programs are impeded by rigid fixed-price contracts because they reduce the government's ability to observe what is happening during the life of the contract.

More recently, in the 1980s, Navy Secretary John Lehman advocated fixed-price development as a means of saving the government money and shifting risk from the government to the contractor. The policy was adopted for a number of development programs, not all of them Navy, and was successful in shifting risk to the contractors, with the result that several contractors have sustained huge losses on fixed-price development contract. In reaction, Congress precluded the use of fixed-price development contracts that exceed $10 million without approval from the Under Secretary of Defense, in the 1989 National Defense Authorization Act.

2. Benefits and Weaknesses

In theory, the DoD selects a contract type that will provide a reasonable distribution of risk between government and industry. Fixed-price contracts provide the greatest risk to contractors, and also award the highest profit rate [59]. Firm-fixed-price contracts closely resemble commercial contracts. The contractor takes all the financial risk, and any profits depend on how well the contractor controls costs. In this way, an FFP contract provides the contractor with an incentive to avoid waste.

Another great advantage of FFP contracts for the government is that they are relatively easy and inexpensive to administer. FFP also benefits the contractor: the government does not monitor contractor costs, so the contractor does not have to conform accounting methods to DoD audit procedures. Administrative costs are therefore lowered.

For the contractor, the expected benefits of the firm-fixed-price contract are as follows:

- Higher profit potential,
- Minimum government control, and
- Minimum government auditing.

On the other hand, the contractor may have to assume all the financial and technical risk and the risk of greater liability for work being performed [59]. This is particularly a problem in development, when the design is not yet established.

Realistically, two important conditions should exist before a firm-fixed-price contract is negotiated:

- Reasonably definite design or performance specifications must be available, and
- The contracting parties must be able to establish at the outset prices that are judged to be fair and reasonable.

In formally advertised procurements, the existence of definite specifications and adequate competition satisfies these conditions. Even when price competition is not present, a firm-fixed-price contract may be appropriate if one of the following conditions exists:

- Historical price comparisons can be made,
- Available cost or pricing data permit realistic estimates of probable performance and costs, and

- Contract performance uncertainties can be so clearly identified that their impact on price can be evaluated.

When none of these conditions exists, the use of a fixed-price contract with an incentive feature, or a cost-reimbursement type of contract, is normally considered more appropriate. Fixed-price contracts are often used for late production lots, when the system and production methods are well-defined.

3. Analysis

Because there is relatively little production experience in these firm-fixed-price development programs, our conclusions are tentative. Our analysis of 10 fixed-price versus 91 non-fixed-price programs indicates that the development cost growth of the firm-fixed-price development programs is 47 percentage points higher than that of the non-fixed price ones. The limited production cost growth data we have shows a mix of outcomes for fixed-price development programs; on average, their cost growth is much higher.

The development cost and schedule outcomes for FPD programs are presented in Table X-3. As can be seen from the table, development outcomes for FPD programs have varied widely. Both the V-22 and the T-AO-187 indicate negative development cost growth. The T-AO-187's low cost growth may reflect low technical risk, while the V-22 is a relatively new program and may not have had time for cost growth to accumulate. The E6A, also a new program, has only three years of production experience. Nevertheless, most of the FPD programs have high development cost growth. Particularly high are Cheyenne (109 percent) and JTIDS (319 percent).

The development cost and schedule outcomes of FPD programs are compared to non-FPD programs in Table X-4.

4. Findings and Recommendations

Fixed-price development contracts do not solve the problems of cost growth and schedule slippage. Most firm-fixed-price contracts examined were written for programs in which the element of uncertainty was high (AMRAAM and V-22, for example). When a contractor fails to perform, the government often amends the contract and allows an increase in price. In some cases, a contractor who fails to perform may be required to accept some loss along with the contract change. For example, contract changes forced contractors to absorb losses on the F-111, SRAM, AMRAAM, T-45, C-17, and AH-56A programs.

Table X-3. Outcomes for FPD Programs

Systems	Years of Production	DCG	TPCG	DSG
V-22	—	-11%	--	0%
Cheyenne	—	109%	—	0%
JTIDS	—	319%	—	65%
F-14D	1	27%	—	0%
T-45TS	2	—	—	—
AMRAAM	2	46%	—	96%
E-6A	3	12%	-7%	31%
Stinger-RMP	4	30%	—	63%
Sgt. York	7	29%	203%	15%
T-AO-187	7	-3%	-8%	5%
F-14A	19	45%	29%	16%

Note: Cost growth figures are weighted by the current estimate.

Table X-4. Outcomes for Programs With and Without FPD (Percent)

Outcome Measure	With FPD	Without FPD
DCG	71 (10)	25 (90)
TPCG	80 (4)	44 (78)
DSG	29 (10)	35 (91)
DQG	36 (9)	7 (89)

Notes: Numbers in parentheses are numbers of programs. Cost growth figures are weighted by the current estimate.

Based on our interviews with the government, it appears that FPD contracts are seldom executed as planned and have to be reopened. The government has difficulty with this, because there is no planned budget to address the problems. If there are problems in development, either the development contract is renegotiated, or there is high cost growth in production, or both.

In short, firm-fixed-price contracts have not been used effectively in development programs. They have not been successful in high-value, high-cost, high-risk, long-term programs.

Since most of the SAR programs are high risk, it is not appropriate to use FPD in these programs. FPD contributes to cost growth in development and in the total program.

XI. CONCLUSIONS AND RECOMMENDATIONS

Acquisition programs have had varying degrees of success in developing and producing weapon systems on time and within budget. On average, total program cost growth was 47 percent—28 percent in development and 56 percent in production. Development schedules (Milestone II to IOC) grew by an average of about one-third over the plan. There is, of course, great variability in these measures depending on program characteristics and management strategies.

The equipment types with the highest total program cost growth were tactical munitions (103 percent). The lowest cost growth was exhibited by ships (15 percent) followed by satellites (20 percent). The highest development cost growth was for vehicles (104 percent). The lowest development cost growth measure was for strategic missiles (5 percent).

Development schedules are particularly important for readiness considerations—the system should be ready when planned. The groups with the highest development schedule growth were vehicles and air-launched tactical munitions while the lowest was tactical aircraft.

We would expect that programs that succeed very similar systems (dubbed modification programs, or mods) would have lower cost growth than completely new programs. Here, there were some surprising results. As we expected, mods overall had lower cost growth than new systems. For some equipment types, however, the technical difficulty of modification programs is underestimated just as badly as that of new programs. This was particularly true for air-launched tactical munitions in development and for vehicles and electronic aircraft in production.

Acquisition managers should consider making more use of prototyping. Prototyping before FSD greatly reduced development cost growth. The major goal of prototyping is to reduce technical risk. However, we see the benefits in reducing cost growth. This greater predictability of development cost enhances the DoD's credibility in developing support for further investments in a program. This study did not specifically address the style of prototyping currently under discussion, the increased use of advanced technology demonstrators without production. More study is needed of this new strategy.

However, our results do have one clear implication for the "new prototyping" issue. The research we have undertaken clearly shows the practical value of the SAR reporting system in providing data evaluating acquisition programs. While the SARs have imperfections, they are extremely valuable. The use of advanced technology demonstrators to keep programs from proceeding to FSD should not diminish the importance of cost and schedule estimating, reporting, and monitoring.

Contract incentives, if successful, are an inexpensive way to induce contractors to reduce costs. Our results, which showed that contract incentives work well in development, were intuitively appealing, but our measurement was very simplistic. We believe that the DoD should undertake further study of the effectiveness of the different types of contract incentives using more sophisticated measurement techniques and the times they are applied in the program.

Multi-year procurement appears to be a successful initiative, as practiced by the DoD using congressional guidelines. However, our results do not guarantee success if multi-year procurement is increased. MYP implies some protection from budgetary pressures, and it is impossible to offer such protection to all programs. To a certain extent, the programs that were procured using MYP were allowed this privilege because they were already successfully managed.

Design-to-cost needs to be implemented early to be successful; otherwise, it does not make sense. The record of dual-sourcing is mixed but favorable for ships and tactical munitions, and the techniques for evaluating its impact have not always been carefully applied. The era of fixed-price development in the early 1980s, is now over. Our results indicate that it should not be revived. Neither should total package procurement.

DoD can use this information to target the classes of programs that showed the highest cost and schedule growth—the tactical munitions, ground combat programs, and electronics/avionics programs—for increased management attention.

When making decisions about future programs, DoD can use the cost and schedule records of past programs of the same equipment type, or programs in the same time period, or programs using similar acquisition strategies. For this reason, it is important that the database be kept up to date with each annual release of the Selected Acquisition Reports.

APPENDIX A

VARIABLE DEFINITIONS AND ACQUISITION PROGRAM DATABASE

APPENDIX A

VARIABLE DEFINITIONS AND ACQUISITION PROGRAM DATA

Table A-1. Demographics Variables

Variable	Definition
89ID	Assigned ID numbers
Full Name	Program name
EQTYPE	Code for Equipment Type (Volume I classification): 0—Satellites 1—Tactical Aircraft 2—Electronic Aircraft 3—Other Aircraft 4—Helicopters 5—Air-Launched Tactical Munitions 6—Surface Launched Tactical Munitions 7—All Electronics/Avionics 8—Strategic Missiles 9—Vehicles 10—Ships
EQTYPE2	Code for Equipment Type (Volume II classification): 0—Satellites 1—Tactical Aircraft 2—Electronic Aircraft 3—Other Aircraft 4—Helicopters 5—Air-Launched Tactical Munitions 6—Surface Launched Tactical Munitions 7—Electronics/Avionics 8—Strategic Missiles 9—Vehicles and Ground Combat Programs 10—Ships and Ship Electronics
BASEYR	Base year used in SARs
FSDST	FSD start year
SVCE	Code for lead Service: 1—Army 2—Navy 3—Air Force
MOD	Code to indicate Modification (vs. New) programs: 0—New program 1—Mod program

Table A-2. Statistics Summary Variables

Variable	Definition
DCG	Development Cost Growth Index
DSG	Development Schedule Growth
DQG	Development Quantity Growth
PCG	Production Cost Growth Index
PSG	Production Schedule Growth
PQG	Production Quantity Growth
TPCG	Total Program Cost Growth Index

Table A-3. Cost and Quantity Data Variables

Variable	Definition
DQ_CE	Current Estimate of Development Quantity
DC_DE	Development Estimate of Development Cost, as stated in SAR (base year)
DC_V1CE	Current Estimate of Development Cost through end of development of first version, as calculated from SAR (base year dollars)
PQ_CE	Current Estimate of Production Quantity
PC_DE	Development Estimate of Production Cost, as stated in SAR (base year)
MC_DE	Development Estimate of Military Construction costs (base year)
TPC_DE	Development Estimate of Total Program costs (base year) = (DC_DE) + (PC_DE) + (MC_DE)

Table A-4. Schedule Data Variables

Variable	Definition
M2_DE	Development Estimate of Milestone II date
M2_CE	Current Estimate of Milestone II date
IOC_DE	Development Estimate of IOC date
IOC_CE	Current Estimate of IOC date
M3_DE	Development Estimate of Milestone III date
M3_CE	Current Estimate of Milestone III date
P_END_DE	Development Estimate of Production End date
P_END_CE	Current Estimate of Production End date
DS_DE	Development Estimate of Development Schedule duration (in months) = (IOC_DE) - (M2_DE)
DS_CE	Current Estimate of Development Schedule duration (in months) = (IOC_CE) - (M2_CE)
PS_DE	Development Estimate of Production Schedule duration (in months) = (P_END_DE) - (M3_DE)
PS_CE	Current Estimate of Production Schedule duration (in months) = (P_END_CE) - (M3_CE)
TS	Total Schedule (in months) = (DS_CE) + (PS_CE)
STRETCH	Program Stretch = (PSG)/(PQG)

Table A-5. Acquisition Initiatives Variables

Variable	Definition
A series of dummy variables (with one exception, as noted below)	0—if initiative does not apply 1—if initiative applies to program
PRO	Prototyping
C_FSD	Competitive FSD (Dual or Multiple Source)
C_PROD	Competitive Production (Dual Source)
DTC	Design-To-Cost
MYP	Multi-Year Procurement
MYP2	Multi-Year Procurement description 1—MYP in first version 2—Immature MYP in first version, < 3 years MYP experience 3—MYP Candidate 4—MYP in later version 0—All others
FPD	Fixed-Price Development
TPP	Total Package Procurement
I_FSD	Contract Incentives in FSD
I_PROD	Contract Incentives in Production

Table A-6. Demographics Data

89ID	Full Name	EQTYPE	EQTYPE2	BASEYR	FSDST	SVCE	MOD
1	Osprey (V-22)	3	3	86	86	2	0
2	T45TS	3	3	84	84	2	0
3	B-1A	3	3	70	70	3	0
4	C-5B	3	3	80	82	3	1
5	C-17A	3	3	81	85	3	0
6	C-5A	3	3	65	65	3	0
7	B-1B	3	3	81	82	3	1
8	FB-111A	3	3	66	66	3	0
9	AV-8A	1	1	70	70	2	0
10	F-5E	1	1	71	72	3	0
11	F-15A/B	1	1	70	70	3	0
12	F-16	1	1	75	75	3	0
13	F-14D	1	1	89	84	2	1
14	F-14A	1	1	69	69	2	0
15	AV-8B	1	1	79	79	2	1
16	A-10	1	1	70	73	3	0
17	F/A-18	1	1	75	76	2	0
18	E-6A	2	2	82	83	2	0
19	E-3A	2	2	70	70	3	0
20	EF-111A	2	2	73	75	3	1

Table A-6. Demographics Data (Continued)

89ID	Full Name	EQTYPE	EQTYPE2	BASEYR	FSDST	SVCE	MOD
21	E-2C	2	2	68	70	2	1
22	EA-6B	2	2	68	68	2	0
23	P-3C	2	2	68	65	2	1
24	LAMPS Mark III	2	2	76	77	2	0
25	E-4	2	2	74	73	3	0
26	S-3A	2	2	68	69	2	0
27	Chinook (CH-47D)	4	4	75	75	1	1
28	Kiowa (OH-58D)	4	4	82	81	1	0
29	Blackhawk (UH-60A/L)	4	4	71	72	1	0
30	Apache (AH-64A)	4	4	72	76	1	0
31	Cheyenne	4	4	66	66	1	0
32	Phoenix (AIM-54A)	5	5	63	62	2	0
33	AMRAAM	5	5	78	82	3	0
34	Hellfire	5	5	75	76	1	0
35	HARM	5	5	78	78	2	0
36	Sparrow (AIM-7F)	5	5	68	66	2	1
37	TOW	5	5	66	63	1	0
38	Sidewinder (AIM-9L)	5	5	71	71	2	1
39	TOW2	5	5	84	78	1	1
40	Harpoon	5	5	70	73	2	0
41	Maverick (D/G)	5	5	75	76	3	1
42	Sparrow (AIM-7E)	5	5	69	60	2	1
43	Sparrow (AIM-7M)	5	5	78	78	2	1
44	Sidewinder (AIM-9M)	5	5	89	76	2	1
45	Phoenix (AIM-54C)	5	5	77	77	2	1
46	ADDS	7	7	83	85	1	0
47	MLS	7	7	82	88	3	0
48	JTIDS	7	7	81	81	3	0
49	JSTARS	7	7	83	84	3	0
50	WIS	7	7	82	85	3	0
51	SINCGARS	7	7	84	78	1	0
52	ASPJ	7	7	84	81	2	0
53	LANTIRN	7	7	80	80	3	0
54	TRI-TAC	7	7	76	75	3	0
55	OTH-B	7	7	82	82	3	0
56	DMSP	0	0	75	76	3	0
57	Navstar GPS	0	0	79	79	3	0
58	DSP	0	0	78	67	3	0
59	DSCS III	0	0	77	76	3	0
60	Improved Hawk	6	6	89	64	1	1
61	Shillelagh	6	6	64	59	1	0
62	MK-48 ADCAP	6	6	89	82	2	1
63	MK-50	6	6	84	83	2	0
64	MK-48	6	6	72	68	2	0
65	Stinger (B/P)	6	6	72	75	1	0
66	Copperhead	6	6	75	75	1	0

Table A-6. Demographics Data (Continued)

89ID	Full Name	EQTYPE	EQTYPE2	BASEYR	FSDST	SVCE	MOD
67	5" Guided Projectile	6	6	77	77	2	0
68	Stinger RMP	6	6	83	84	1	1
69	Dragon	6	6	66	66	1	0
70	Pershing II	6	6	79	79	1	1
71	Patriot	6	6	72	72	1	0
72	Standard Missile 2	6	6	84	72	2	1
73	Lance	6	6	70	67	1	0
74	Peacekeeper	8	8	82	78	3	0
75	GLCM	8	8	77	78	3	1
76	Tomahawk	8	8	77	77	2	1
77	SRAM II	8	8	83	87	3	0
78	Minuteman II	8	8	69	65	3	1
79	Trident II Missile	8	8	83	83	2	1
80	Small ICBM	8	8	84	86	3	0
81	ALCM	8	8	77	77	3	0
82	SRAM	8	8	66	66	3	0
83	Minuteman III	8	8	67	66	3	1
84	Condor	5	5	70	66	2	0
85	Maverick (A)	5	5	68	68	3	0
86	ASAS/ENSCE	7	9	86	84	1	1
87	Bradley M2/M3	9	9	72	72	1	0
88	FAADS_L-R	6	9	89	86	1	0
89	M1 Tank	9	9	72	76	1	0
90	MLRS	6	9	78	77	1	0
91	M60 A2	9	9	65	65	1	1
92	M198 Howitzer	6	9	72	70	1	0
93	Roland	6	9	75	75	1	0
94	Sergeant York	6	9	78	78	1	0
95	AN/BSY-2	7	10	86	87	2	0
96	SURTASS/T-AGOS	10	10	75	74	2	0
97	CG47	10	10	78	78	2	1
98	DDG 51	10	10	87	83	2	0
99	FFG 7	10	10	73	72	2	0
100	LHA	10	10	69	69	2	0
101	LHD 1	10	10	82	82	2	1
102	LSD 41	10	10	81	78	2	1
103	LSD41 Cargo	10	10	88	87	2	1
104	SSN 21	10	10	85	85	2	0
105	SSN 688	10	10	71	68	2	0
106	T-AO 187	10	10	84	81	2	0
107	AEGIS	7	10	70	69	2	0
108	AN/BSY-1	7	10	84	83	2	0
109	DDG 963	10	10	70	70	2	0

Table A-7. Statistics Summary Data

89ID	Full Name	DCG	DSG	DQG	PCG	PSG	PQG	TPCG
1	Osprey (V-22)	0.89	1.00	.	.	.	.	.
2	T45TS	.	.	.	.	.	.	.
3	B-1A	1.10	1.17	0.80	.	.	.	.
4	C-5B	.	.	.	0.77	1.00	1.00	0.76
5	C-17A	1.39	1.16	1.00	.	.	.	.
6	C-5A	.	.	.	2.15	1.19	0.66	1.77
7	B-1B	1.17	1.00	1.00	0.96	0.73	1.00	0.99
8	FB-111A	2.57	1.42	1.00	1.79	.	0.29	1.83
9	AV-8A	.	.	.	0.99	.	0.96	0.99
10	F-5E	1.05	1.06	1.00	0.79	1.27	1.79	0.88
11	F-15A/B	1.07	1.03	1.00	1.20	2.25	1.74	1.16
12	F-16	1.20	0.98	1.00	1.21	4.51	4.61	1.21
13	F-14D	1.27	1.00	1.00	.	.	.	.
14	F-14A	1.45	1.16	2.00	1.25	3.27	1.26	1.29
15	AV-8B	1.28	1.01	1.00	0.86	1.47	0.82	0.92
16	A-10	1.27	1.08	0.71	1.34	1.72	1.00	1.33
17	F/A-18	1.15	1.08	1.00	1.43	1.81	1.45	1.38
18	E-6A	1.12	1.31	1.00	0.85	0.62	1.07	0.93
19	E-3A	1.37	1.16	3.00	1.19	2.56	0.74	1.25
20	EF-111A	2.10	1.70	1.00	1.62	0.87	1.00	1.73
21	E-2C	1.61	0.76	1.00	1.34	1.37	3.61	1.41
22	EA-6B	1.26	1.00	1.00	1.59	2.76	1.57	1.50
23	P-3C	1.22	1.00	.	1.17	1.79	3.04	1.19
24	LAMPS Mark III	1.04	1.00	1.00	1.37	2.04	1.00	1.29
25	E-4	1.88	1.59	1.00	0.70	1.00	0.50	1.11
26	S-3A	1.09	1.00	0.67	1.36	1.00	0.95	1.30
27	Chinook (CH-47D)	1.13	1.06	1.00	1.34	1.49	1.31	1.32
28	Kiowa (OH-58D)	0.98	1.19	1.00	1.34	1.00	0.42	1.30
29	Blackhawk (UH-60A/L)	1.01	1.05	0.63	1.28	2.29	2.04	1.23
30	Apache (AH-64A)	1.20	1.49	1.00	1.85	0.94	1.51	1.65
31	Cheyenne	2.09	1.00	1.00	.	.	.	.
32	Phoenix (AIM-54A)	1.54	1.19	0.82	1.36	0.98	0.98	1.39
33	AMRAAM	1.46	1.96	0.66	.	.	.	.
34	Hellfire	1.09	1.44	0.95	1.71	1.75	2.31	1.44
35	HARM	1.25	1.60	1.00	1.10	2.08	1.65	1.13
36	Sparrow (AIM-7F)	4.25	2.82	3.94	1.58	1.22	1.66	1.75
37	TOW	1.20	1.46	1.01	1.78	2.27	0.59	1.70
38	Sidewinder (AIM-9L)	4.89	2.45	4.10	2.07	2.76	1.23	2.25
39	TOW2	1.00	1.00	1.00	0.95	1.44	1.24	0.95
40	Harpoon	0.93	1.36	1.00	1.94	2.37	1.31	1.60
41	Maverick (D/G)	1.07	1.98	0.94	1.55	1.36	0.63	1.51
42	Sparrow (AIM-7E)	0.84	1.00	1.00	1.08	3.11	0.34	1.07
43	Sparrow (AIM-7M)	0.98	1.50	1.00	1.28	1.61	1.41	1.26
44	Sidewinder (AIM-9M)	2.04	1.01	1.94	1.01	2.44	2.27	1.10
45	Phoenix (AIM-54C)	1.67	1.45	1.50	1.98	1.50	3.52	1.92
46	ADDS	1.75	2.27	1.00	.	.	.	.

Table A-7. Statistics Summary Data (Continued)

89ID	Full Name	DCG	DSG	DQG	PCG	PSG	PQG	TPCG
47	MLS	.	.	.	.	.	.	.
48	JTIDS	4.19	1.65	3.05	.	.	.	.
49	JSTARS	1.40	1.00	1.06	.	.	.	.
50	WIS	1.25	2.33	1.00	.	.	.	.
51	SINCGARS	.	.	.	.	.	.	.
52	ASPJ	2.31	1.91	1.00	.	.	.	.
53	LANTIRN	0.96	.	1.00	1.20	1.00	0.81	1.16
54	TRI-TAC	1.02	0.93	1.00	0.87	1.54	1.19	0.88
55	OTH-B	1.11	1.63	1.00	1.10	2.50	1.14	1.07
56	DMSP	1.02	.	1.00	1.22	1.29	1.13	1.15
57	Navstar GPS	1.03	1.62	1.00	1.24	1.71	1.93	1.11
58	DSP	1.64	.	1.00	1.00	1.25	1.40	1.10
59	DSCS III	1.84	1.62	1.00	1.70	0.87	1.08	1.74
60	Improved Hawk	1.87	1.25	1.00	3.07	3.16	1.49	2.75
61	Shillelagh	1.31	1.05	1.38	1.54	1.44	0.89	1.47
62	MK-48 ADCAP	1.08	1.34	1.00	1.00	1.53	1.00	1.02
63	MK-50	1.30	1.36	1.00	.	.	.	.
64	MK-48	1.83	0.89	0.57	1.00	1.59	0.68	1.08
65	Stinger (B/P)	2.02	1.64	0.92	1.84	0.82	0.40	1.87
66	Copperhead	1.28	1.73	0.78	2.23	1.15	0.19	2.12
67	5" Guided Projectile	1.16	1.00	0.65	.	.	.	.
68	Stinger RMP	1.30	1.63	1.50	.	.	.	.
69	Dragon	1.88	2.14	1.05	2.72	1.13	0.27	2.59
70	Pershing II	1.00	0.83	0.82	2.31	1.46	0.71	1.68
71	Patriot	1.40	1.12	0.83	1.78	1.15	0.44	1.68
72	Standard Missile 2	1.44	1.00	1.00	0.91	1.67	1.36	0.96
73	Lance	1.08	1.46	1.09	1.20	1.86	2.00	1.12
74	Peacekeeper	0.95	1.00	1.00	1.21	1.90	0.78	1.10
75	GLCM	3.48	1.30	0.83	1.62	1.30	0.80	1.81
76	Tomahawk	1.31	1.48	0.91	1.57	1.29	3.35	1.45
77	SRAM II	.	.	.	.	.	.	.
78	Minuteman II	1.00	1.71	1.00	1.24	.	1.00	1.14
79	Trident II Missile	0.93	1.04	0.93	.	.	.	.
80	Small ICBM	0.31	1.00	0.14	.	.	.	.
81	ALCM	1.37	1.34	0.69	1.18	1.69	0.51	1.23
82	SRAM	2.80	2.03	1.00	5.56	.	2.14	3.63
83	Minuteman III	0.98	0.87	0.73	1.69	.	1.13	1.39
84	Condor	1.72	3.00	1.19	6.53	1.12	0.02	5.13
85	Maverick (A)	1.04	1.34	0.91	0.99	1.14	1.18	1.01
86	ASAS/ENSCE	1.49	1.49	1.00	.	.	.	.
87	Bradley M2/M3	3.16	1.23	1.40	3.59	1.00	1.93	3.50
88	FAADS_L-R	1.05	1.00	1.00	.	.	.	.
89	M1 Tank	1.54	0.94	1.00	1.36	0.46	0.75	1.40
90	MLRS	1.02	1.06	0.77	0.88	1.72	1.66	0.92
91	M60 A2	1.28	3.17	1.00	2.21	0.90	0.91	2.15
92	M198 Howitzer	1.35	1.30	1.00	1.29	0.91	0.89	1.31

Table A-7. Statistics Summary Data (Continued)

89ID	Full Name	DCG	DSG	DQG	PCG	PSG	PQG	TPCG
93	Roland	1.52	2.15	1.00	4.83	0.43	0.15	4.19
94	Sergeant York	1.29	1.15	1.00	3.16	0.49	0.10	3.03
95	AN/BSY-2	.	.	.	.	.	.	.
96	SURTASS/T-AGOS	1.78	1.38	1.00	1.63	1.54	1.50	1.68
97	CG47	1.23	0.92	1.00	0.94	1.14	1.69	0.94
98	DDG 51	1.39	1.20	1.00	0.94	2.11	4.22	0.99
99	FFG 7	1.40	1.15	1.00	1.59	1.83	1.02	1.59
100	LHA	1.00	1.56	1.00	1.58	1.80	0.56	1.57
101	LHD 1	1.09	1.06	1.00	0.94	1.49	2.00	0.94
102	LSD 41	1.09	1.04	1.00	0.92	1.00	0.67	0.92
103	LSD41 Cargo	.	.	.	.	.	.	.
104	SSN 21	1.35	1.04	1.00	.	.	.	.
105	SSN 688	0.92	1.66	1.00	0.99	1.60	6.20	0.99
106	T-AO 187	0.97	1.05	1.00	0.92	1.02	1.06	0.92
107	AEGIS	1.28	0.96	1.00	.	.	.	.
108	AN/BSY-1	1.41	1.00	.	.	.	.	.
109	DDG 963	1.06	1.40	1.00	1.23	2.17	1.03	1.23

Note: A period (.) in a cell denotes missing values or incomplete or classified data.

Table A-8. Cost and Quantity Data

89ID	Full Name	DQ_CE	DC_DE	DC_V1CE	PQ_CE	PC_DE	MC_DE	TPC_DE
1	Osprey (V-22)	0	2,444	2,170	.	20,493	136	23,073
2	T45TS	2	1,150	506	300	2,604	0	3,755
3	B-1A	4	2,431	2,671	.	7,423	0	9,854
4	C-5B	0	0	.	50	5,724	122	5,846
5	C-17A	1	2,704	3,756	210	16,793	47	19,545
6	C-5A	5	1,042	1,026	76	2,328	44	3,413
7	B-1B	0	2,539	2,976	100	17,961	0	20,500
8	FB-111A	1	85	219	76	1,696	0	1,782
9	AV-8A	.	0	.	110	504	0	504
10	F-5E	5	101	106	147	191	0	292
11	F-15A/B	20	1,658	1,778	1266	4,333	0	5,991
12	F-16	8	579	693	2999	3,798	0	4,377
13	F-14D	0	1,465	1,865	437	13,628	12	15,104
14	F-14A	12	900	1,308	583	4,492	0	5,391
15	AV-8B	6	873	1,113	276	4,862	6	5,741
16	A-10	10	282	359	727	1,487	0	1,768
17	F/A-18	11	1,438	1,652	1157	6,561	18	8,017
18	E-6A	1	293	328	15	1,292	0	1,585
19	E-3A	3	761	1,040	31	1,390	0	2,151
20	EF-111A	2	84	177	40	295	0	379
21	E-2C	2	129	208	101	402	0	531
22	EA-6B	5	234	295	72	584	0	818
23	P-3C	1	203	248	316	1,091	0	1,294

Table A-8. Cost and Quantity Data (Continued)

89ID	Full Name	DQ_CE	DC_DE	DC_VICE	PQ_CE	PC_DE	MC_DE	TPC_DE
24	LAMPS Mark III	5	527	550	204	1,483	7	2,017
25	E-4	1	159	299	3	255	29	443
26	S-3A	4	565	618	183	1,896	0	2,461
27	Chinook (CH-47D)	3	76	86	472	806	0	883
28	Kiowa (OH-58D)	5	214	210	243	1,454	0	1,668
29	Blackhawk (UH-60A/L)	10	358	361	2,257	1,584	0	1,942
30	Apache (AH-64A)	9	609	729	807	1,283	0	1,892
31	Cheyenne	10	126	263	.	0	0	126
32	Phoenix (AIM-54A)	37	94	144	2,285	442	0	536
33	AMRAAM	111	562	823	24,320	4,032	0	4,594
34	Hellfire	229	210	230	56,716	278	0	488
35	HARM	99	227	284	22,657	1,455	0	1,682
36	Sparrow (AIM-7F)	134	25	106	16,145	380	0	405
37	TOW	472	98	118	137,275	629	0	727
38	Sidewinder (AIM-9L)	123	13	66	11,350	189	0	202
39	TOW2	113	90	90	174,532	2,163	0	2,253
40	Harpoon	52	272	254	3,766	523	0	795
41	Maverick (D/G)	33	100	107	19,733	895	0	995
42	Sparrow (AIM-7E)	44	22	19	19,661	1,247	0	1,269
43	Sparrow (AIM-7M)	44	55	53	15,592	859	0	914
44	Sidewinder (AIM-9M)	134	66	134	16,937	701	0	767
45	Phoenix (AIM-54C)	45	74	123	2,483	297	2	372
46	ADDS	3	175	306	120	1,806	0	1,982
47	MLS	6	35	28	316	48	0	82
48	JTIDS	168	309	1,296	.	0	NA	309
49	JSTARS	19	1,185	1,656	118	3,753	88	5,026
50	WIS	1	545	681	34	642	2	1,190
51	SINCGARS	123	154	191	364,802	4,013	0	4,168
52	ASPJ	12	228	527	.	0	NA	228
53	LANTIRN	12	420	404	1,067	1,682	0	2,102
54	TRI-TAC	9	37	38	416	306	0	344
55	OTH-B	1	327	364	8	711	107	1,145
56	DMSP	1	225	229	9	413	3	640
57	Navstar GPS	12	926	956	54	623	8	1,558
58	DSP	4	401	657	21	2,123	26	2,549
59	DSCS III	2	134	247	13	313	0	447
60	Improved Hawk	55	309	578	9,823	863	1	1,173
61	Shillelagh	564	111	146	88,260	246	0	357
62	MK-48 ADCAP	48	1,212	1,311	.	5,021	16	6,250
63	MK-50	108	1,118	1,452	.	3,609	9	4,736
64	MK-48	60	150	276	2,771	1,540	0	1,690
65	Stinger (B/P)	205	76	154	9,290	334	0	411
66	Copperhead	320	105	135	24,546	738	0	843
67	5" Guided Projectile	141	95	110	.	0	0	95
68	Stinger RMP	9	36	46	59,059	2,215	0	2,251
69	Dragon	822	62	116	67,561	343	0	404

Table A-8. Cost and Quantity Data (Continued)

89ID	Full Name	DQ_CE	DC_DE	DC_VICE	PQ_CE	PC_DE	MC_DE	TPC_DE
70	Pershing II	28	583	582	278	616	0	1,198
71	Patriot	5	1,106	1,554	103	3,121	40	4,267
72	Standard Missile 2	88	648	932	14,677	5,923	.	6,572
73	Lance	168	418	451	2,126	220	0	638
74	Peacekeeper	20	6,018	5,745	173	10,292	325	16,635
75	GLCM	5	75	261	560	928	51	1,054
76	Tomahawk	74	783	1,025	3,630	1,024	0	1,806
77	SRAM II	0	861	791	1,633	860	0	1,721
78	Minuteman II	48	1,437	1,436	620	2,467	351	4,255
79	Trident II Missile	28	9,057	8,393	871	14,988	533	24,578
80	Small ICBM	3	9,777	3,040	.	22,207	1,727	33,711
81	ALCM	24	708	972	1,763	2,312	121	3,141
82	SRAM	0	162	454	1,500	63	0	225
83	Minuteman III	44	1,835	1,801	794	2,764	75	4,674
84	Condor	128	126	216	50	308	.	434
85	Maverick (A)	186	116	121	20100	215	1	332
86	ASAS/ENSCE	.	.	.	.	.	.	.
87	Bradley M2/M3	21	98	311	2,300	227	0	326
88	FAADS_L-R	0	13	13	1,207	1,133	0	1,145
89	M1 Tank	13	423	649	2,488	1,970	0	2,393
90	MLRS	504	261	268	4,813	1,971	0	2,233
91	M60 A2	3	14	18	543	192	0	206
92	M198 Howitzer	10	31	42	584	80	0	111
93	Roland	4	160	244	27	678	0	838
94	Sergeant York	4	163	211	64	2,043	0	2,207
95	AN/BSY-2	0	1,566	1,819	31	NA	0	.
96	SURTASS/T-AGOS	1	59	106	18	147	0	206
97	CG47	0	56	68	27	8,958	14	9,027
98	DDG 51	0	892	1,241	38	6,794	26	7,712
99	FFG 7	0	14	20	51	2,606	0	2,620
100	LHA	0	22	22	5	1,269	0	1,291
101	LHD 1	0	40	44	6	2,892	0	2,932
102	LSD 41	0	47	51	8	3,177	0	3,224
103	LSD41 Cargo	0	15	13	6	1,335	0	1,351
104	SSN 21	0	1,725	2,332	9	1,425	84	3,233
105	SSN 688	0	5	5	62	5,127	17	5,149
106	T-AO 187	0	16	15	18	2,592	0	2,608
107	AEGIS	1	394	504	65	NA	0	.
108	AN/BSY-1	.	2,027	2,849	31	NA	0	.
109	DDG 963	0	36	38	31	2,372	0	2,408

Note: A period (.) in a cell denotes missing values or incomplete or classified data.

Table A-9. Schedule Data

89ID	Full Name	M2 DE	M2 CE	IOC DE	IOC CE	M3 DE	M3 CE	P_END_DE	P_END_CE	DS_DE	DS_CE	PS_DE	PS_CE	TS	STRETCH
1	Osprey (V-22)	Apr-86	Apr-86	Sep-92	Sep-92	Jan-89	Mar-89	Sep-97	Sep-89	77	77	104	6	41	.
2	T45TS	Sep-84	Oct-84	May-91	Jun-91	Sep-87	Sep-87	Sep-95	Sep-97	80	80	96	120	155	.
3	B-1A	Jun-70	Jun-70	Mar-79	Sep-80	Sep-74	Dec-76	.	.	105	123	.	.	.	.
4	C-5B	Oct-82	Oct-82	Dec-85	Dec-85	Dec-82	Dec-82	Mar-89	Mar-89	38	38	75	75	77	1.00
5	C-17A	Nov-84	Feb-85	Jan-92	Jun-93	Nov-87	Jan-89	Dec-98	Sep-99	86	100	133	128	175	.
6	C-5A	Oct-65	Oct-65	Dec-69	Sep-70	Aug-66	Aug-66	Apr-72	May-73	50	59	68	81	91	1.80
7	B-1B	Jan-82	Jan-82	Sep-86	Sep-86	Jan-82	Jan-82	Jun-88	Sep-86	56	56	77	56	56	0.73
8	FB-111A	Jan-66	Feb-66	Mar-69	Aug-70	.	.	Sep-69	Oct-71	38	54	.	.	68	.
9	AV-8A	Jan-68	.	.	.	Nov-70	Nov-70	.	.	.	.	.	.	.	.
10	F-5E	Dec-72	Aug-72	Jun-74	Mar-74	Mar-73	Jul-73	Sep-75	Sep-76	18	19	30	38	49	0.71
11	F-15A/B	Jan-70	Jan-70	Jul-75	Sep-75	Oct-72	Oct-72	Sep-79	May-88	66	68	83	187	220	1.30
12	F-16	Mar-75	Apr-75	Aug-78	Aug-78	Jan-77	Jan-77	Aug-81	Sep-97	41	40	55	248	269	0.98
13	F-14D	Jul-84	Jul-84	Mar-92	Mar-92	Feb-88	Mar-88	Dec-98	Dec-98	92	92	130	129	173	.
14	F-14A	Feb-69	Feb-69	Apr-73	Dec-73	Mar-71	Dec-70	Sep-76	Dec-88	50	58	66	216	238	2.60
15	AV-8B	Jun-79	Jul-79	Jun-85	Aug-85	Apr-82	Apr-82	Sep-88	Sep-91	72	73	77	113	146	1.79
16	A-10	Jan-73	Jan-73	Jun-77	Oct-77	May-74	Jul-74	Sep-79	Sep-83	53	57	64	110	128	1.72
17	F/A-18	Jan-76	Jan-76	Sep-82	Mar-83	Nov-78	Nov-78	Sep-88	Sep-96	80	86	118	214	248	1.25
18	E-6A	May-83	Apr-83	Sep-88	Apr-90	Dec-83	Feb-86	Sep-89	Sep-89	64	84	69	43	77	0.58
19	E-3A	Jul-70	Jul-70	Mar-77	Apr-78	Dec-74	Mar-75	Jul-78	May-84	80	93	43	110	166	3.47
20	EF-111A	Jan-75	Jan-75	Apr-80	Dec-83	Mar-78	Mar-79	Sep-85	Sep-85	63	107	90	78	128	0.87
21	E-2C	May-69	Sep-70	Nov-73	Feb-74	Oct-70	Sep-71	Sep-81	Sep-86	54	41	131	180	192	0.38
22	EA-6B	Jan-68	Jan-68	Jun-71	Jun-71	Nov-70	Nov-70	Sep-73	Sep-78	41	41	34	94	128	1.77
23	P-3C	Sep-65	Sep-65	Sep-69	Sep-69	Sep-67	Sep-67	Sep-81	Sep-92	48	48	168	300	324	0.59
24	LAMPS Mark III	Sep-77	Sep-77	Jul-84	Jul-84	Dec-82	Dec-82	Sep-89	Sep-96	82	82	81	165	228	2.04
25	E-4	Jan-73	Feb-73	Jun-74	May-75	May-80	May-80	Nov-85	Nov-85	17	27	66	66	153	2.00
26	S-3A	Aug-69	Aug-69	Feb-74	Feb-74	Apr-72	Apr-72	Dec-74	Dec-74	54	54	32	32	64	1.05
27	Chinook (CH-47D)	Oct-75	Oct-75	Aug-83	Feb-84	Sep-80	Oct-80	Sep-88	Sep-92	94	100	96	143	203	1.14
28	Kiowa (OH-58D)	Sep-81	Sep-81	Jun-86	May-87	Oct-84	Oct-85	Sep-89	Sep-90	57	68	59	59	108	2.38
29	Blackhawk (UH-60A/L)	Jun-71	Jun-71	Jun-79	Nov-79	Dec-76	Dec-76	Sep-91	Sep-10	96	101	177	405	471	1.12
30	Apache (AH-64A)	Dec-76	Dec-76	May-83	Jul-86	Oct-80	Apr-82	Sep-89	Sep-90	77	115	107	101	165	0.63
31	Cheyenne	Mar-66	Mar-66	Aug-72	Aug-72	.	.	.	.	77	77	.	.	.	.
32	Phoenix (AIM-54A)	Apr-69	Apr-69	Mar-73	Dec-73	Sep-70	Nov-70	Sep-79	Sep-79	47	56	108	106	125	1.00
33	AMRAAM	Sep-82	Sep-82	Aug-86	May-90	Feb-84	Jun-87	Sep-94	Sep-98	47	92	127	135	192	.
34	Hellfire	Feb-76	Feb-76	May-83	Jul-86	Feb-80	Mar-82	Sep-86	Sep-93	87	125	79	138	211	0.76
35	HARM	Feb-78	Feb-78	Sep-81	Nov-83	Sep-81	Mar-83	Sep-87	Sep-95	43	69	72	150	211	1.26
36	Sparrow (AIM-7F)	May-65	Dec-65	Jan-69	Apr-76	Jan-68	Oct-74	Sep-73	Sep-81	44	124	68	83	189	0.74

Table A-9. Schedule Data (Continued)

89ID	Full Name	M2 DE	M2 CE	IOC DE	IOC CE	M3 DE	M3 CE	P_END_DE	P_END_CE	DS_DE	DS_CE	PS_DE	PS_CE	TS	STRETCH
37	TOW	Apr-63	Apr-63	May-68	Sep-70	Aug-66	Nov-68	Sep-72	Sep-82	61	89	73	166	233	3.85
38	Sidewinder (AIM-9L)	Jun-71	Aug-71	Mar-74	May-78	Apr-74	Apr-76	Sep-77	Sep-85	33	81	41	113	169	2.25
39	TOW2	Sep-78	Sep-78	Sep-83	Sep-83	Sep-81	Sep-81	Sep-90	Sep-94	60	60	108	156	192	1.17
40	Harpoon	Jun-73	Jun-73	Jun-76	Jul-77	Jun-74	Jul-74	Sep-81	Sep-91	36	49	87	206	219	1.80
41	Maverick (D/G)	Sep-76	Sep-76	Jun-81	Feb-86	Jun-79	Mar-82	Sep-85	Sep-90	57	113	75	102	168	2.14
42	Sparrow (AIM-7E)	Jan-60	Jan-60	Dec-63	Dec-63	Jan-62	Jan-62	Sep-65	Jun-73	47	47	44	137	161	9.15
43	Sparrow (AIM-7M)	Apr-78	Apr-78	Jun-81	Jan-83	Jun-81	Nov-82	Sep-85	Sep-89	38	57	51	82	137	1.14
44	Sidewinder (AIM-9M)	Feb-76	Feb-76	Aug-82	Sep-82	Dec-80	Feb-81	Sep-85	Sep-92	78	79	57	139	199	1.07
45	Phoenix (AIM-54C)	Oct-76	Oct-76	Oct-83	Dec-86	Jul-79	Dec-79	Sep-86	Sep-90	84	122	86	129	167	0.43
46	ADDS	Sep-84	Apr-85	Sep-88	May-94	Sep-86	Feb-88	Sep-89	Sep-99	48	109	36	139	173	.
47	MLS	Jun-86	Aug-88	Sep-89	Jul-92	Oct-88	Mar-91	Sep-94	Sep-97	39	47	71	78	109	.
48	JTIDS	Jan-81	Jan-81	Sep-88	Sep-93	Jun-86	Feb-90	.	.	92	152	.	.	.	.
49	JSTARS	Aug-84	Aug-84	Mar-91	Mar-91	Sep-87	Sep-87	Sep-02	Sep-02	79	79	180	180	217	.
50	WIS	May-85	Jul-85	Nov-87	May-91	Nov-87	Nov-87	Sep-89	Sep-94	30	70	22	82	110	.
51	SINCGARS	Apr-78	Apr-78	Oct-87	Dec-90	Dec-83	Dec-83	Sep-98	Sep-04	114	152	177	249	317	.
52	ASPJ	Dec-81	Aug-81	Jul-87	Apr-92	Aug-86	Jun-89	.	.	67	128	.	.	.	.
53	LANTIRN	Jul-80	Jul-80	.	.	Feb-85	Feb-85	Sep-91	Sep-91	.	.	79	79	134	1.23
54	TRI-TAC	May-75	May-75	Sep-89	Sep-88	Apr-82	Apr-82	Sep-89	Sep-93	172	160	89	137	220	1.30
55	OTH-B	Jun-82	Jun-82	Sep-87	Jan-91	May-84	May-84	Sep-87	Sep-92	63	103	40	100	123	2.19
56	DMSP	Dec-76	Dec-76	.	.	Sep-83	Sep-83	Sep-90	Sep-92	.	.	84	108	189	1.14
57	Navstar GPS	Jun-79	Jun-79	Dec-87	Mar-93	Sep-83	Jun-86	Sep-89	Sep-96	102	165	72	123	207	0.89
58	DSP	Sep-66	Sep-67	.	.	Sep-69	Sep-69	Sep-89	Sep-94	.	.	240	300	324	0.89
59	DSCS III	Dec-76	Dec-76	Mar-82	Jun-85	Jan-80	Dec-81	Sep-94	Sep-94	63	102	176	153	213	0.80
60	Improved Hawk	Nov-64	Nov-64	Apr-71	Nov-72	Apr-69	Jun-69	Sep-75	Sep-89	77	96	77	243	298	2.12
61	Shillelagh	Jun-59	Jun-59	Jan-67	Jun-67	Nov-64	Nov-64	Jun-69	Jun-71	91	96	55	79	144	1.61
62	MK-48 ADCAP	Sep-82	Sep-82	Feb-87	Aug-88	Mar-85	Sep-85	Sep-93	Sep-98	53	71	102	156	192	1.53
63	MK-50	Dec-83	Jan-84	Apr-89	Apr-91	Oct-86	Mar-89	Sep-95	Sep-99	64	87	107	126	188	.
64	MK-48	Apr-68	Jun-68	Apr-71	Feb-71	Jan-70	Oct-70	Dec-75	Mar-80	36	32	71	113	141	2.35
65	Stinger (B/P)	May-72	May-72	Sep-77	Feb-81	Aug-75	Nov-77	Sep-82	Sep-83	64	105	85	70	136	2.04
66	Copperhead	Jun-75	Jun-75	Oct-79	Dec-82	Feb-78	Nov-79	Sep-86	Sep-89	52	90	103	118	171	6.19
67	5" Guided Projectile	Nov-77	Nov-77	Dec-81	Dec-81	.	.	.	.	49	49	.	.	.	.
68	Stinger RMP	Sep-84	Sep-84	Nov-87	Nov-89	Aug-85	Aug-85	Sep-96	Sep-96	38	62	133	133	144	.
69	Dragon	Feb-66	Feb-66	May-70	Mar-75	Dec-68	Mar-72	Sep-74	Sep-78	51	109	69	78	151	4.13
70	Pershing II	Feb-79	Feb-79	Dec-84	Dec-83	Oct-83	Jun-82	Sep-86	Sep-86	70	58	35	51	91	2.07
71	Patriot	Mar-72	Mar-72	Apr-82	Jun-83	Apr-79	Sep-80	Sep-89	Sep-92	121	135	125	144	246	2.62
72	Standard Missile 2	Jun-72	Jun-72	Sep-77	Sep-77	Mar-85	Mar-85	Sep-89	Sep-92	63	63	54	90	243	1.22

Table A-9. Schedule Data (Continued)

89ID	Full Name	M2 DE	M2 CE	IOC DE	IOC CE	M3 DE	M3 CE	P_END_DE	P_END_CE	DS_DE	DS_CE	PS_DE	PS_CE	TS	STRETCH
73	Lance	May-67	Dec-67	Jun-70	Jun-72	Jan-69	Jan-71	Sep-73	Sep-79	37	54	56	104	141	0.93
74	Peacekeeper	Dec-78	Dec-78	Dec-86	Dec-86	Jan-84	Jan-84	Sep-90	Sep-96	96	96	80	152	213	2.45
75	GLCM	Jan-77	Jan-77	May-82	Dec-83	May-81	Oct-83	Sep-86	Sep-90	64	83	64	83	164	1.61
76	Tomahawk	Jan-77	Jan-77	Jan-82	Jun-84	Sep-80	Dec-84	Sep-86	Sep-92	60	89	72	93	188	0.39
77	SRAM II	Jun-87	Aug-87	Apr-93	Sep-94	Jul-91	Feb-92	Sep-94	Sep-96	70	85	38	55	109	.
78	Minuteman II	Oct-65	Oct-65	Dec-66	Oct-67	.	Apr-73	.	Sep-78	14	24	.	65	155	.
79	Trident II Missile	Oct-83	Oct-83	Dec-89	Mar-90	Mar-87	Apr-87	Sep-96	Sep-02	74	77	114	185	227	.
80	Small ICBM	Dec-86	Dec-86	Dec-92	Dec-92	Dec-89	Dec-89	Sep-99	Sep-99	72	72	117	117	153	.
81	ALCM	Jan-77	Jan-77	Jun-81	Dec-82	Feb-80	Apr-80	Sep-85	Sep-89	53	71	67	113	152	3.28
82	SRAM	Nov-66	Nov-66	Jul-69	Apr-72	Sep-69	Dec-70	.	Sep-74	32	65	.	45	94	.
83	Minuteman III	Oct-68	Sep-69	May-71	Dec-71	.	.	Sep-73	Sep-83	31	27	.	.	168	.
84	Condor	Jun-66	Jun-66	Nov-69	Sep-76	Mar-69	Oct-73	Sep-72	Sep-77	41	123	42	47	135	56.00
85	Maverick (A)	Jul-68	Jul-68	Dec-71	Feb-73	Jul-71	Jul-71	Sep-78	Sep-79	41	55	86	98	134	0.96
86	ASAS/ENSCE	Dec-84	Dec-84	Nov-87	Apr-89	Mar-87	Mar-87	Sep-89	Sep-06	35	52	30	234	261	.
87	Bradley M2/M3	Nov-72	Nov-76	Aug-78	Dec-83	Feb-80	Feb-80	Sep-84	Sep-84	69	85	55	55	94	0.52
88	FAADS_L-R	Nov-86	Nov-86	Sep-89	Sep-89	Aug-87	Aug-87	Sep-97	Sep-97	34	34	121	121	130	.
89	M1 Tank	Jul-76	Nov-76	Dec-80	Jan-81	Feb-79	Apr-79	Sep-88	Sep-83	53	50	115	53	82	0.61
90	MLRS	Jan-77	Jan-77	Nov-82	Mar-83	May-80	May-80	Sep-88	Sep-94	70	74	100	172	212	1.04
91	M60 A2	Mar-65	Mar-65	Mar-68	Sep-74	Aug-67	Mar-68	Sep-73	Sep-73	36	114	73	66	102	1.00
92	M198 Howitzer	Dec-70	Dec-70	May-77	Apr-79	May-75	Dec-76	Sep-81	Sep-82	77	100	76	69	141	1.02
93	Roland	Jan-75	Jan-75	Jun-79	Jul-84	Apr-78	May-79	Sep-83	Sep-81	53	114	65	28	80	2.87
94	Sergeant York	Feb-77	Nov-77	Mar-85	Mar-87	Oct-80	May-82	Aug-87	Sep-85	97	112	82	40	94	4.71
95	AN/BSY-2	Nov-87	Feb-88	Jul-95	May-95	Dec-95	May-96	Sep-99	Sep-99	92	87	45	40	139	.
96	SURTASS/T-AGOS	Oct-74	Oct-74	Mar-81	Aug-83	May-77	Jan-81	Sep-81	Sep-87	77	106	52	80	155	1.03
97	CG47	Jan-78	Jan-78	Mar-84	Sep-83	Jan-78	Jan-78	Sep-92	Sep-94	74	68	176	200	200	0.67
98	DDG 51	May-83	Dec-83	Mar-90	Feb-92	Aug-86	Oct-86	Sep-93	Sep-01	82	98	85	179	213	0.50
99	FFG 7	Oct-72	Oct-72	May-78	Mar-79	Mar-75	Dec-75	Sep-82	Sep-89	67	77	90	165	203	1.80
100	LHA	Dec-68	Apr-69	Feb-74	May-77	Oct-70	Jan-71	Sep-76	Sep-81	62	97	71	128	149	3.25
101	LHD 1	Jul-82	Jul-82	Apr-90	Oct-90	Jun-83	Jun-83	Sep-93	Sep-98	93	99	123	183	194	0.74
102	LSD 41	Nov-78	Nov-78	Nov-85	Feb-86	Jan-81	Jan-81	Sep-92	Sep-92	84	87	140	140	166	1.50
103	LSD41 Cargo	Dec-87	Dec-87	Sep-94	Oct-94	Jul-89	Nov-89	Sep-99	Sep-99	81	82	122	118	141	.
104	SSN 21	May-85	Jun-85	Nov-94	May-95	Mar-90	Jun-88	Sep-97	Sep-99	114	119	90	135	171	.
105	SSN 688	Nov-68	Nov-68	Sep-73	Nov-76	Jan-71	Jan-71	Sep-87	Sep-97	58	96	200	320	346	0.26
106	T-AO 187	Dec-81	Dec-81	Nov-86	Feb-87	Nov-82	Nov-82	Mar-94	Jun-94	59	62	136	139	150	0.97
107	AEGIS	Dec-69	Dec-69	Mar-84	Sep-83	May-75	Jan-78	Sep-93	Sep-01	171	165	220	284	381	.
108	AN/BSY-1	Sep-83	Sep-83	Mar-90	Mar-90	Dec-95	May-96	Sep-99	Sep-99	78	78	45	40	192	.
109	DDG 963	Jun-70	Jun-70	Jun-75	Jun-77	Jan-73	Jun-72	Dec-77	Feb-83	60	84	59	128	152	2.10

Table A-10. Acquisition Initiatives Data

89ID	Full Name	PRO	C_FSD	C_PROD	DTC	MYP	MYP2	FPD	TPP	I_FSD	I_PROD
1	Osprey (V-22)	1	0	.	0	.	0	1	0	1	.
2	T45TS	0	0	0	0	0	0	1	0	0	0
3	B-1A	0	0	0	0	0	0	0	0	1	1
4	C-5B	0	0	0	0	0	0	0	0	0	0
5	C-17A	1	0	.	0	.	0	0	0	1	.
6	C-5A	0	0	0	0	0	0	0	1	1	1
7	B-1B	0	0	0	0	1	1	0	0	0	1
8	FB-111A	0	0	0	0	0	0	0	0	0	0
9	AV-8A	1	0	0	0	0	0	0	0	0	0
10	F-5E	1	0	0	0	0	0	0	0	1	1
11	F-15A/B	0	0	0	0	0	3	0	0	1	1
12	F-16	1	0	0	1	1	1	0	0	1	1
13	F-14D	0	0	0	0	0	0	1	0	0	0
14	F-14A	0	0	0	0	0	0	1	0	1	0
15	AV-8B	1	0	0	1	1	2	0	0	1	1
16	A-10	1	0	0	1	0	0	0	0	1	1
17	F/A-18	0	0	0	1	0	3	0	0	1	1
18	E-6A	0	0	0	0	0	0	1	0	0	0
19	E-3A	1	0	0	0	0	0	0	0	1	1
20	EF-111A	0	0	0	1	0	0	0	0	1	0
21	E-2C	0	0	0	0	0	0	0	0	1	0
22	EA-6B	0	0	0	0	0	0	0	0	0	0
23	P-3C	0	0	0	0	0	0	0	0	1	1
24	LAMPS Mark III	1	0	0	1	0	0	0	0	1	1
25	E-4	0	0	0	0	0	0	0	0	1	0
26	S-3A	0	0	0	0	0	0	0	0	1	1
27	Chinook (CH-47D)	0	0	0	1	1	1	0	0	0	1
28	Kiowa (OH-58D)	0	0	0	1	0	0	0	0	1	0
29	Blackhawk (UH-60A/L)	1	0	0	1	1	1	0	0	1	1
30	Apache (AH-64A)	1	0	0	1	0	2	0	0	0	1
31	Cheyenne	1	0	0	0	0	0	1	0	0	0
32	Phoenix (AIM-54A)	1	0	0	0	0	0	0	0	0	1
33	AMRAAM	1	0	1	1	0	0	1	0	0	0
34	Hellfire	1	1	1	1	0	0	0	0	1	0
35	HARM	1	0	0	1	0	3	0	0	1	1
36	Sparrow (AIM-7F)	0	0	1	0	0	0	0	0	1	1
37	TOW	1	0	1	0	1	1	0	0	0	1
38	Sidewinder (AIM-9L)	0	0	1	1	0	0	0	0	1	1
39	TOW2	0	0	0	0	1	2	0	0	1	1
40	Harpoon	1	0	0	1	0	3	0	0	1	1
41	Maverick (D/G)	1	0	1	1	0	2	0	0	1	1
42	Sparrow (AIM-7E)	0	0	0	0	0	0	0	0	1	1
43	Sparrow (AIM-7M)	1	0	1	1	0	0	0	0	1	1
44	Sidewinder (AIM-9M)	0	0	1	1	0	0	0	0	0	0
45	Phoenix (AIM-54C)	0	0	1	0	0	0	0	0	1	1
46	ADDS	1	0	0	0	0	0	0	0	0	0

Table A-10. Acquisition Initiatives Data (Continued)

89ID	Full Name	PRO	C_FSD	C_PROD	DTC	MYP	MYP2	FPD	TPP	I_FSD	I_PROD
47	MLS	0	0	.	0	.	0	0	0	0	.
48	JTIDS	1	0	.	0	.	0	1	0	0	.
49	JSTARS	0	1	0	0	0	0	0	0	1	1
50	WIS	0	0	0	0	0	0	0	0	1	0
51	SINCGARS	1	0	1	0	0	0	0	0	0	0
52	ASPJ	1	0	0	0	0	0	0	0	0	0
53	LANTIRN	1	1	0	0	0	0	0	0	0	0
54	TRI-TAC	0	0	0	0	0	0	0	0	0	0
55	OTH-B	1	0	0	0	0	0	0	0	0	1
56	DMSP	0	0	0	0	1	1	0	0	1	1
57	Navstar GPS	0	0	0	1	1	1	0	0	1	0
58	DSP	0	0	0	0	1	1	0	0	1	1
59	DSCS III	0	0	0	1	1	1	0	0	1	0
60	Improved Hawk	0	0	0	0	1	2	0	0	1	1
61	Shillelagh	0	0	1	0	1	1	0	0	1	1
62	MK-48 ADCAP	0	0	1	0	0	0	0	0	1	1
63	MK-50	1	0	1	1	0	0	0	0	1	0
64	MK-48	0	0	0	0	0	0	0	0	1	1
65	Stinger (B/P)	0	0	1	1	0	0	0	0	1	1
66	Copperhead	1	0	0	1	0	0	0	0	0	1
67	5" Guided Projectile	0	0	0	1	0	0	0	0	1	0
68	Stinger RMP	0	0	0	1	1	1	1	0	1	1
69	Dragon	0	0	1	0	0	0	0	0	0	0
70	Pershing II	0	0	0	1	0	0	0	0	1	0
71	Patriot	0	0	0	1	1	1	0	0	1	1
72	Standard Missile 2	0	0	1	0	0	0	0	0	1	1
73	Lance	0	0	0	0	0	0	0	0	1	1
74	Peacekeeper	0	0	0	0	0	0	0	0	1	1
75	GLCM	0	1	0	0	0	0	0	0	0	0
76	Tomahawk	0	0	1	0	0	0	0	0	0	0
77	SRAM II	0	0	0	0	0	0	0	0	1	1
78	Minuteman II	0	0	0	0	0	0	0	0	1	1
79	Trident II Missile	0	0	0	0	0	0	0	0	1	1
80	Small ICBM	1	0	0	0	0	0	0	0	1	0
81	ALCM	0	1	0	1	0	0	0	0	1	1
82	SRAM	0	0	0	0	0	0	0	1	0	0
83	Minuteman III	0	0	0	0	0	0	0	0	1	1
84	Condor	0	0	0	1	0	0	0	0	1	1
85	Maverick (A)	0	0	0	0	0	0	0	1	0	0
86	ASAS/ENSCE	1	0	0	0	0	0	0	0	0	0
87	Bradley M2/M3	1	0	0	1	0	4	0	0	1	0
88	FAADS_L-R	0	1	0	0	0	0	0	0	0	0
89	M1 Tank	1	1	0	1	0	4	0	0	1	1
90	MLRS	1	1	0	1	1	1	0	0	1	0
91	M60 A2	0	0	0	0	0	0	0	0	0	0
92	M198 Howitzer	1	0	0	0	1	1	0	0	0	0

Table A-10. Acquisition Initiatives Data (Continued)

89ID	Full Name	PRO	C_FSD	C_PROD	DTC	MYP	MYP2	FPD	TPP	I_FSD	I_PROD
93	Roland	0	0	0	0	0	0	0	0	1	1
94	Sergeant York	0	1	0	1	0	0	1	0	0	1
95	AN/BSY-2	1	1	0	1	0	0	0	0	1	1
96	SURTASS/T-AGOS	1	1	1	1	1	1	0	1	0	1
97	CG47	1	0	1	0	0	0	0	0	1	1
98	DDG 51	0	0	1	1	0	0	0	0	NA	1
99	FFG 7	1	1	1	1	0	0	0	0	1	1
100	LHA	0	0	0	NA	0	0	0	1	1	1
101	LHD 1	0	0	1	1	0	0	0	0	1	1
102	LSD 41	0	1	1	1	0	0	0	0	1	1
103	LSD41 Cargo	0	0	1	1	1	1	0	0	0	1
104	SSN 21	1	0	1	0	0	0	0	0	0	1
105	SSN 688	0	0	1	NA	1	1	0	0	NA	1
106	T-AO 187	0	0	1	0	0	0	1	0	1	1
107	AEGIS	1	1	0	0	0	0	0	0	1	1
108	AN/BSY-1	1	0	0	1	0	0	0	0	1	1
109	DDG 963	1	0	0	0	0	0	0	1	1	1

APPENDIX B

WEIGHTING OF COST GROWTH

APPENDIX B

WEIGHTING OF COST GROWTH

The average total program cost growth for the sample of programs in the study is 50.6 percent. Calculating a simple mean such as this places the emphasis on the program as an institution, without regard to size.

However, we may also want to consider the impact of cost growth on spending. In that case, it is important to understand that a small percentage cost growth in a large program such as the F-15 amounts to more in terms of dollars than a large percentage growth in a small program such as the AIM-9L. Cost growth generally is less in larger programs, as shown in Figure B-1. (In the case of DE size, the relationship is statistically significant at the .05 level.) This implies that analysis of weighted cost growth is desirable for some applications.

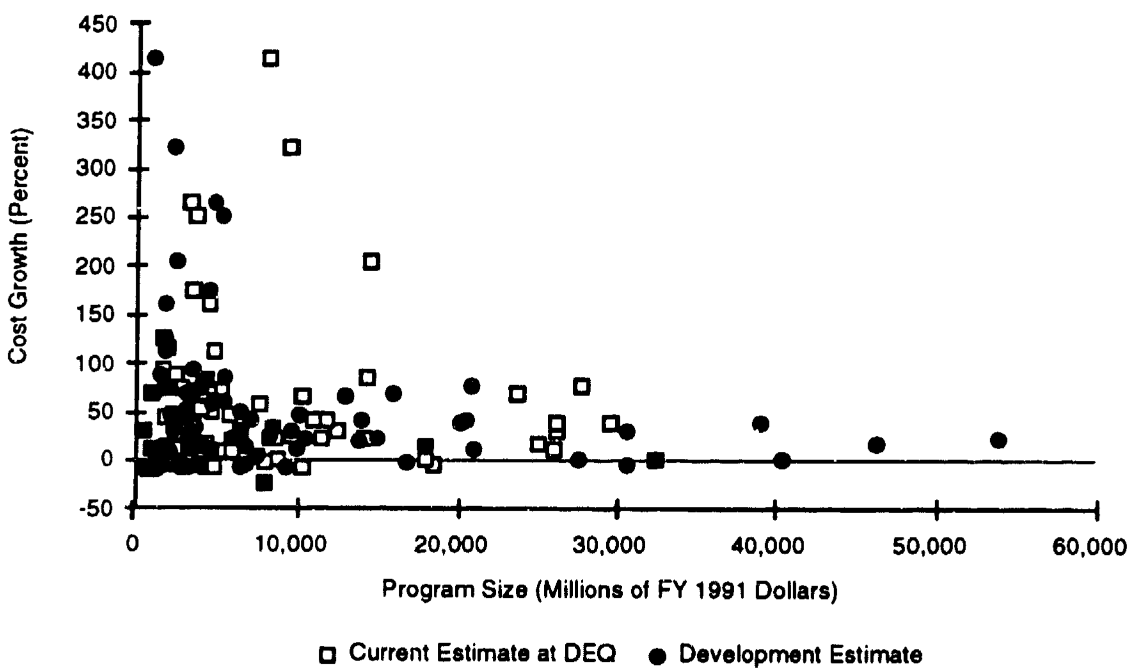


Figure B-1. Total Program Cost Growth by Program Size

In a prior study [1], we weighted cost growth by the size of the program, as measured by the actual cost of the planned quantity.[1] Using the same procedure for data in this study results in a cost growth of 47 percent, which is lower than the unweighted mean but higher than some alternative procedures. Part of the reason for the high value is that relatively high weights are given to such programs as Roland, Condor, and Sgt. York that engaged in minimal production. This procedure has the advantage that it reflects the actual cost of the program that the estimator was asked to estimate.

An alternative procedure is to weight by the planned cost of the program. This procedure results in a mean of 29.4 percent. It reflects the total dollars invested, without regard to the program as an institution. It has the desirable property that it yields the sum of the current estimates divided by the sum of the development estimates.[2]

Yet another alternative is to weight by the latest current estimate, including additional quantity not planned for and additional versions of the system. Early studies of cost growth (see Harman [60 and 61]) used this procedure. This weighting procedure has the desirable property of giving additional credit to successful programs that went through several versions. However, the subsequent versions may not have been subjected to the acquisition initiatives whose impact we are trying to measure, and, often, the line between programs is arbitrary. For example, the F-15 program is still reporting under the title F-15, even though it is on its fifth version, while the F-14 program began reporting separately with the F-14D version.

Table B-1 shows the mean values of the key outcomes, unweighted and weighted using the three alternatives identified here.

---

1 A weighted average is computed in the following manner:

- Each value v_i is multiplied by its weight w_i.
- Both the weights and the products are added.
- The sum of the products is divided by the sum of the weights to obtain the weighted average:

$$\text{weighted average} = \frac{\Sigma\left(v_i w_i\right)}{\Sigma\left(w_i\right)}.$$

Weighted averages are affected by the proportions among the weights but not by the absolute sizes of the weights.

2

$$\frac{\Sigma\left(\frac{CE_i}{DE_i}\right) \times DE_i}{\Sigma\, DE_i} = \frac{\Sigma CE_i}{\Sigma DE_i}.$$

Table B-1. Mean Cost Growth, Unweighted and Using Alternative Weights (Percent)

Outcome Measure	Unweighted	Current Estimate, Original Quantity Weights	Planned Cost Weights	Actual Spending Weights[a]
TPCG	50.6	47.0	29.4	30.9
PCG	58.1	56.5	32.2	33.6
DCG	45.2	29.5	12.8	27.8

a Actual spending weights are approximate for development and for total program, since we have actual development spending in the database for only 26 programs. For the other programs, we used our current estimate weights. The production weights, which represent the greatest part of the total, are exact.

Figure B-2 shows the relative weights for development cost growth. For a given level of cost growth, a horizontal slice through the chart indicates the relative weights. For example, near the top of the chart, in the region of high cost growth, the CE weights are generally the furthest to the right, indicating the highest weights. In the lower part of the chart, the DE weights are more likely to be higher.

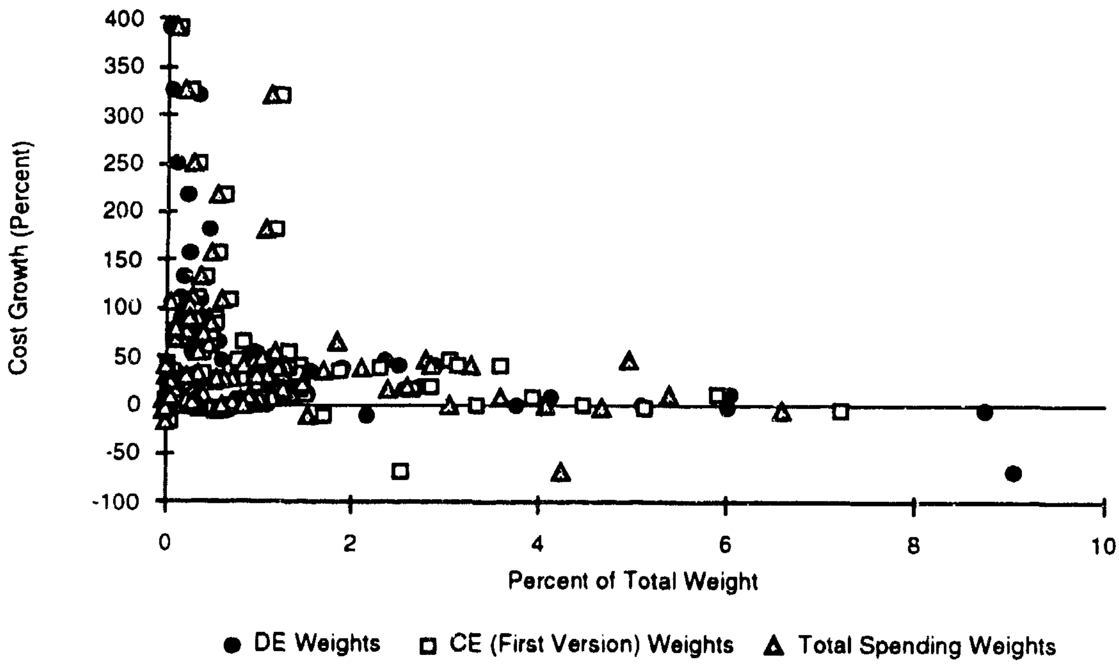


Figure B-2. Development Cost Growth With Different Weights

Figure B-3 shows relative weights for total program cost growth. Again, the same relationship holds.

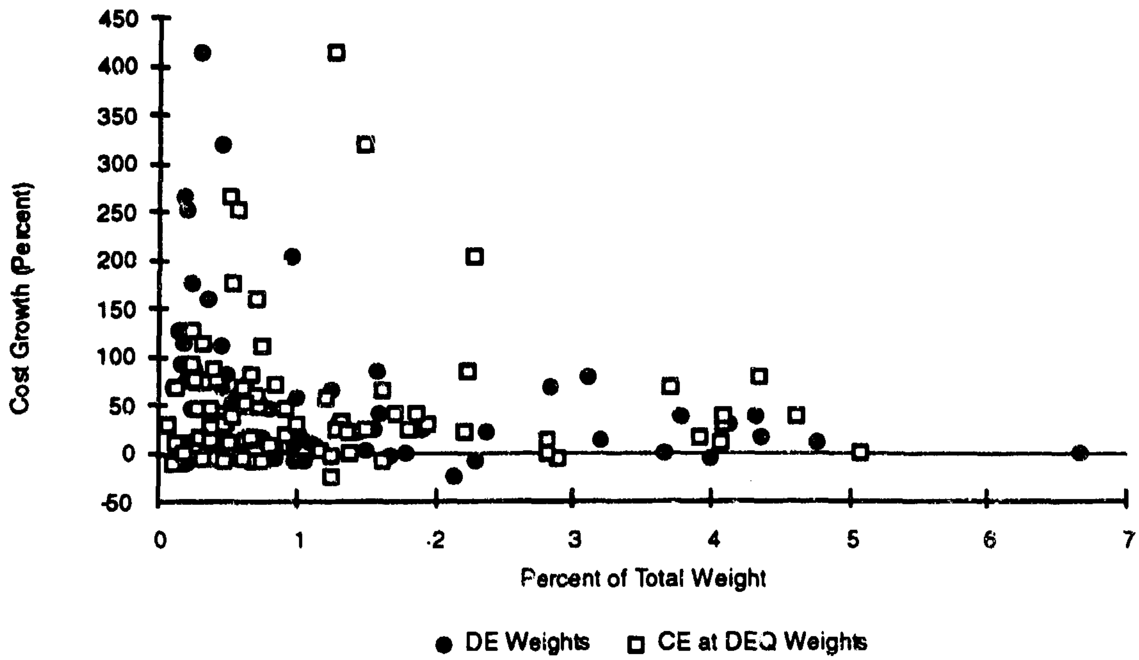


Figure B-3. Total Program Cost Growth With Different Weights

In this study, we have emphasized the relationships between cost growth and factors such as equipment type, program type, and the management initiatives. For that purpose, it is not so much the average values of cost growth as their relative magnitudes that are important. We have used the CE at DEQ weights as our default weighting system. In Section IV, we include the CE weights in the major tables for illustrative purposes. In sections on the initiatives, we note analyses in which weighting makes a difference in the outcome.

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ABBREVIATIONS

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ADCAP	advanced capability
ADDS	Army Data Distribution System
AIFV	Armored Infantry Fighting Vehicle
ALCM	air-launched cruise missile
AMRAAM	Advanced Medium-Range Air-to-Air Missile
ARSV	Armored Reconnaissance Scout Vehicle
ASARC	Army Systems Acquisition Review Council
ASAS	All Source Analysis System
ASPI	aircraft propulsion system integration
ASPJ	Advanced Self-Protection Jammer
ATEGG	advanced turbine engine gas generator
CCDR	Contractor Cost Data Reporting
CE	current estimate
CER	cost-estimating relationships
CICA	Competition in Contracting Act
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DCG	development cost growth
DCGU	development cost growth, unweighted
DCGW	development cost growth, weighted
DCP	development concept paper
DDR&E	Director of Defense Research and Engineering
DE	development estimate
DEQ	development estimate quantity
DoD	Department of Defense
DQG	Development quantity growth
DSARC	Defense Systems Acquisition Review Council
DSB	Defense Science Board
DSG	development schedule growth
DTC	design-to-cost
DTUPC	design-to-unit-production-cost

EMD	engineering and manufacturing development
ESCE	Enemy Situation Correlation Element
FAADS	Forward Area Air Defense System
FFP	firm-fixed price
FPD	fixed-price development
FSD	full-scale development
FVS	Fighting Vehicle System
FY	fiscal year
FYDP	Future-Years Defense Program
GAO	General Accounting Office
GLCM	ground-launched cruise missile
GNP	gross national product
GP	Guided Projectile
HARM	High-Speed Anti-Radiation Missile
HIP	Howitzer Improvement Program
ICBM	intercontinental ballistic missile
IOC	initial operational capability
JTIDS	Joint Surveillance and Target Attack Radar System
LAMPS	Light Airborne Multi-Purpose System
LANTIRN	Low-Altitude Navigation and Targeting Infrared System for Night
LAV	light armored vehicle
LCC	life-cycle cost
LOS-F	line-of-sight forward
LOS-R	line-of-sight rear
MBT	Main Battle Tank
MLRS	Multiple-Launch Rocket System
MLS	multiple launch system
MYP	multi-year procurement
OFPP	Office of Federal Procurement Policy
OSD	Office of the Secretary of Defense
OTH	over-the-horizon
PCG	production cost growth
PCGU	production cost growth, unweighted
PCGW	production cost growth, weighted
PLS	palletized load system
POST	Passive Optical Seeker Technique

PPBS	Planning, Programming, and Budgeting System
PQG	production quantity growth
PSG	production schedule growth
R&D	research and development
RDT&E	research, development, test and evaluation
RMP	Reprogrammable Microprocessor
SAR	Selected Acquisition Report
SINCGARS	Single Channel Ground and Airborne Radio System
SRAM	Short-Range Attack Missile
SURTASS	Surveillance Towed Array Sound System
TOW	tube-launched, optically-tracked, wire-guided
TPCG	total program cost growth
TPCGU	total program cost growth, unweighted
TPCGW	total program cost growth, weighted
TPP	total package procurement
TRI-TAC	Joint Tactical Communications Program
USDRE	Under Secretary of Defense Research and Engineering
UTTAS	Utility Tactical Transport Aircraft System
V/STOL	vertical/short takeoff and landing
VTOL	vertical takeoff and landing
WIS	World Wide Military Command and Control Information System